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EXPERIMENTAL MEASUREMENT OF STRAIN AND ACCELERATION LEVELS IN A RIGID WALL SHELTER SUBJECTED TO ENVIRONMENTAL LOADINGS

by

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DECEMBER 1978

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NATICK RESEARCH and DEVELOPMENT COMMAND
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SHOCK	PORTABLE SHELTERS	

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The details of a study to experimentally measure the stresses induced in a portable rigid wall shelter by loadings typical of the transportation environment are documented. In the transportation configuration the shelter measures 6.1 m long x 2.4 m wide x 2.4 m high (20 ft x 8 ft x 8 ft) and is designed to the requirements of the International Organization for Standardization (ISO). In the deployed configuration the width expands to 6.4 m. The primary construction material is an alumir·ım faced paper honeycomb core sandwich panel.

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The shelter was instrumented with accelerometers and strain gages and subjected to loadings typical of the ISO and military transportation environment. The strain and acceleration data generated during the tests and details of several structural failures are presented.

PREFACE

The author expresses his appreciation to Henry E. Antkowiak, John E. Lanza, Edward M. Rolfes and Walter Zagieboylo, all of the US Army Natick Research and Development Command, for the design of the instrumentation systems, acquisition of the experimental data, and execution of the test program.

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INTRODUCTION

The Army designs and fields a large number of various types of rigid wall tactical shelters. In the closed transportation configuration the shelters serve as their own shipping containers, with space for many component items to be stored inside during shipment. After being moved to a site for deployment, the shelters are leveled; some can be expanded to two, three, or even six times the original floor area, and the associated components are then positioned for immediate use. Presently rigid wall shelters are used in as diverse field capacities as kitchens, bakeries, latrines, hospital units, administrative areas and command posts.

A new generation of Army shelters is being developed which have a standard transportation configuration designed to comply with the requirements of the International Organization for Standardization (ISO). As ISO standard containers, they can be transported internationally by ship, truck, rail and air and are compatible with both military and commercial freight handling equipment.

The Army's ability to produce and field these tactical shelters has progressed more rapidly than its ability to accurately predict critical stress distributions induced in the shelters by applied environmental and transportation-related forces. Knowledge of the stress distribution is required for both a fundamental understanding of the shelter's load-carrying capability and as a basis for the most efficient structural design. Lack of this knowledge presents a technical barrier hindering advancement of the state of the art of tactical shelter design.

A combination analytical and experimental program has been initiated at the Natick Research and Development Command (NARADCOM) in order to surmount the technical barrier. The analytical phase of the program is concerned with investigations of the effects of environmental loads on shelters through the use of theories of solid mechanics, elasticity and computer modeling. The experimental phase of the program is concerned with the measurement of the stresses in both the basic construction material, that is the composite panels, and the complete shelter under simulated and actual loads. Results of the experimental portion will be used both to verify the analytical theory and to provide factual data on the mechanical response of existing shelter systems.

This report details the results of one part of the program: an experimental study to determine the strain distribution profile and acceleration levels induced in a prototype three-for-one expandable ISO-type shelter by loads typical of the commercial and military transportation environment. Results of a complementary analytical study[1] and results

[1] A. R. Johnson, and V. P. Ciras, "Finite Element Analysis of a Statically Loaded ISO Tactical Shelter," NARADCOM Technical Report, under preparation

of studies[2,3] of stresses in the basic sandwich panel construction material will be reported on separately.

OBJECTIVE

The ISO three-for-one expandable shelter selected for test is one of several different prototype units initially constructed to demonstrate the feasibility of the concept of an ISO-type family of Army tactical shelters. The objective of the study is to experimentally determine the response of the instrumented unit to controlled loadings typical of the transportation environment. Results of the study will provide experimental data on the strain distribution pattern in the shelter for use in the complementary finite element analysis and will highlight strengths and weaknesses of the new design. Only transportation-type loadings are considered. Loadings that the shelter would sustain in the deployed configuration such as wind, solar, or snow loads are not addressed in this study.

DESCRIPTION OF THREE-FOR-ONE-SHELTER

The three-for-one (3/1) expandable prototype was constructed by the Brunswick Corporation, Defense Division, Marion, Virginia, under contract to the Natick Research and Development Command as a conceptual model of a standardized general-purpose, rigid-wall shelter with a moderate expansion ratio.

In the closed transportation configuration, Figure 1, the shelter is designed to the dimensional and strength requirements of the International Organization for Standardization type 1C freight container. As such, it must meet the various strength criteria required of certified containers. It measures nominally 2.4 metres high by 2.4 metres wide by 6.1 metres long, has a mass of approximately 2,722 kilograms and a payload of approximately 4,082 kilograms.

In the habitation mode, Figure 2, both sides are expanded to form an inclosed, enviromentally controlled, lighted shelter approximately 2.4 metres high by 6.4 metres wide by 6.1 metres long with about 39 square metres of usable floor space.

[2] A. R. Johnson, "A study of Transversely Loaded Panels Used in Tactical Shelters," NARADCOM Technical Report, under preparation

[3] F. D. Barca, "Experimental Measurement of Strain and Deflection in a Uniformly Loaded Simply Supported Composite Panel," NARADCOM Technical report, Natick/TR-79/018, November 1978

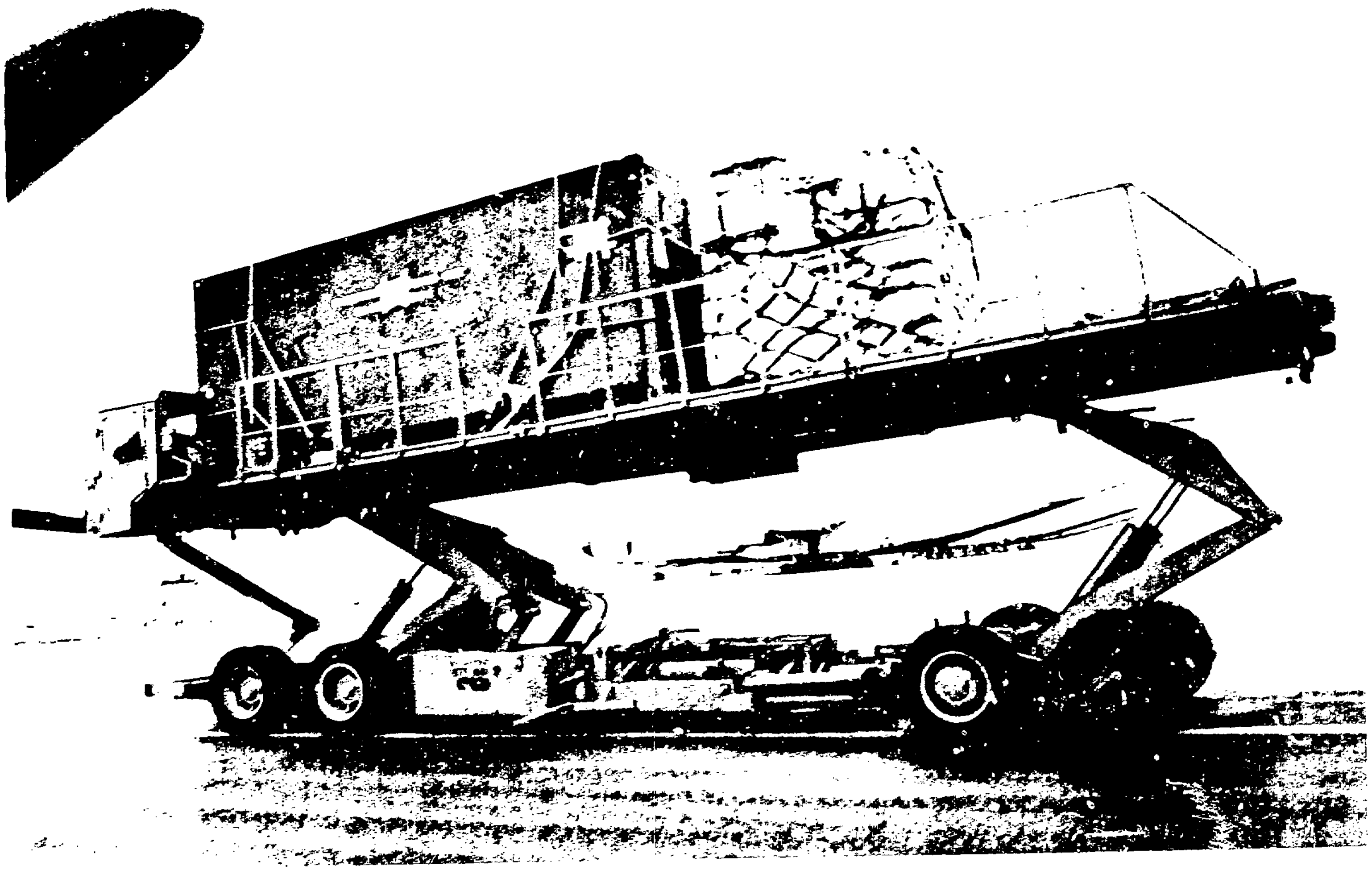


Figure 1. ISO–Type Shelter, Transportation Configuration. Closed ISO-type shelter being loaded into aircraft for transport.

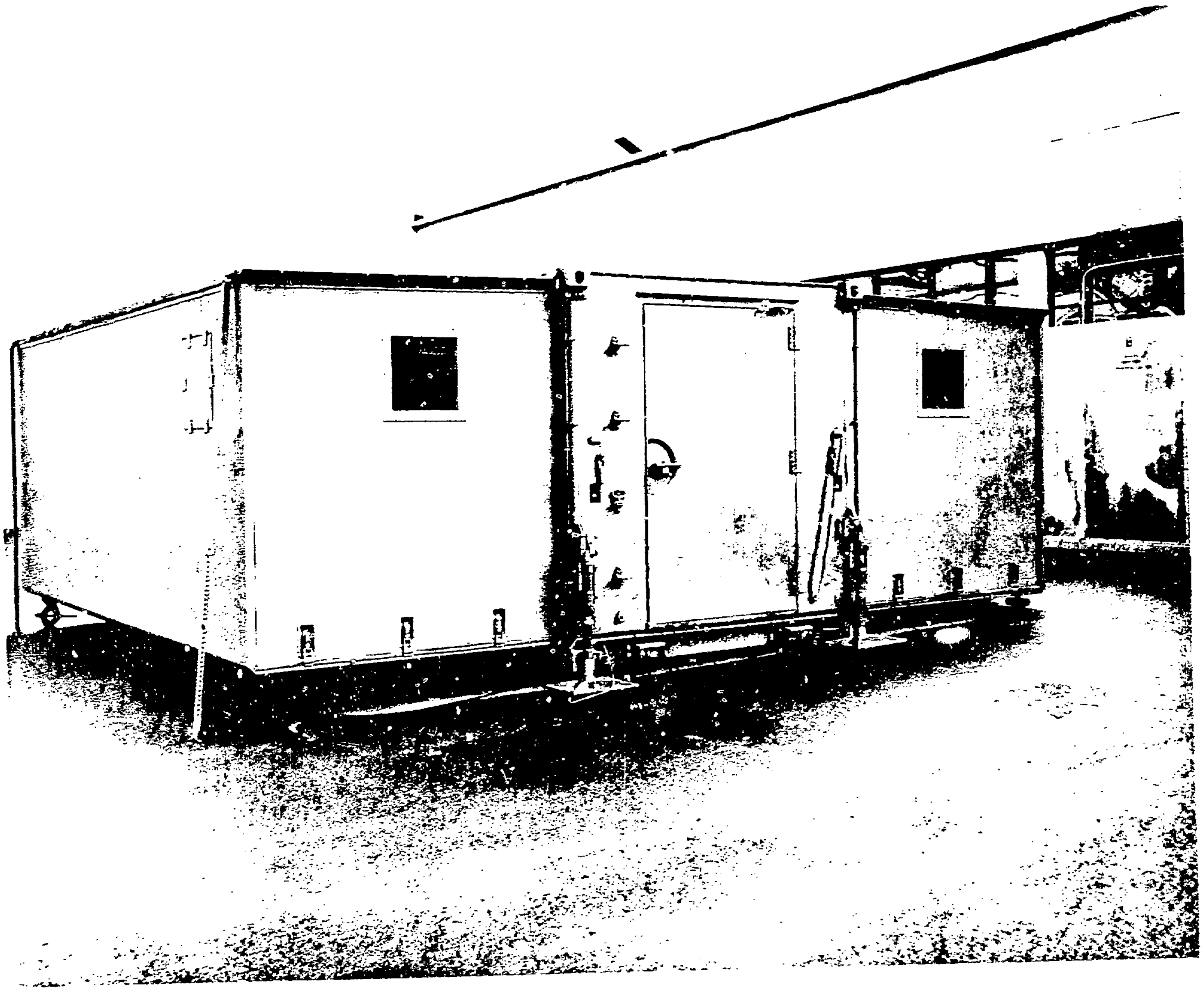


Figure 2. 3/1 Shelter, Expanded Configuration. In the deployed mode the shelter is expanded from both sides and measures approximately 6.1 m long by 6.4 m wide by 2.4 m high.

The primary construction material used in the walls, floor and roof is a lightweight sandwich panel. The panels have a 60.9 kg m³ (3.8 pcf), MIL H 21040[4] kraft paper honeycomb core hot bonded to 5052 H34/H36 aluminum face sheets. Depending upon the application, the panel thicknesses range from 5 cm to 8 cm and the face sheets are generally either 1.02 or 1.27 mm thick. Aluminum extrusions are also incorporated into the panels to increase their strength and are fastened together in the completed shelter to serve as additional load carrying members.

The prototype unit was field tested[5] for transportability, habitability, and function at Fort Hood, Texas, for a period of two months prior to being selected for this study.

DEFINITION OF TRANSPORTATION ENVIRONMENT LOADS

The shelter is transported as a closed van freight container and therefore may be subjected to two classifications of loads, those typical of commercial freight handling operations and those unique to military operations. American National Standard MH 5.1[6] and its companion standard, MH 5.1.1[7], define the magnitude of loads such as stacking, racking, lashing and lifting which the container may encounter in commercial road, rail, sea and air transport. Definition of the probable military loadings is not as straightforward. The national standards mentioned do not directly cover railroad humping, truck transport over very rough terrain, dolly transport, towing, or accidental drops. Military

[4] Military Specification MIL H 21040C, Honeycomb Materials, Water Migration Resistant Type, Structural, Paper Base, 16 July 1974

[5] Maj. W. A. Allen, "Improved Shelters," MASSTER Test Report No. FM 301, Headquarters, MASSTER, Fort Hood, Texas, 31 December 1975

[6] American National Standard ANSI MH 5.1 1971, Basic Requirements for Cargo Containers, American National Standards Institute, Inc., New York, NY, 1971

[7] American National Standard ANSI MH 5.1.1 1971, Requirements for Closed Van Containers, American National Standards Institute, Inc., New York, NY, 1971

specifications[8-12] for shelters, however, generally specify some or all of these tests, although the requirements for a particular test may differ between specifications. Military specifications[13,14] for 6.1-metre containers, on the other hand, generally do not specify any of these tests.

The specifications referenced are not intended to serve as an all-inclusive list. They demonstrate the fact that one military transportation environment for all container/shelter combinations has not been defined. The design engineer selects those requirements, or specifies additional requirements, which in his best judgment are applicable to his item. The specification requirements, however, are a result of years of experience and, as such, were used as a rational basis for defining a series of composite transportation environment tests tailored to the 3/1 shelter. Figure 3 is a listing of the test requirements specified for similar container/shelter combinations and the test requirements finally selected for the 3/1 shelter as representative of its transportation environment.

The stacking, top lift, bottom lift, end wall, and side wall tests selected are identical to the national standards.

The restraint, racking and lashing tests selected are also identical to the national standards with the exception that a one-minute load duration has been added. The one-minute duration standardizes the static simulation of a dynamic condition and prohibits different technicians from applying the loads at different rates and for different time periods, possibly resulting in non-comparable data.

[8] Military Specification MIL-S-28931, Shelters, General Purpose: Expandable, Transportable, 30 June 1969

[9] Military Specification MIL-S-43898A, Shelter, Multi-Purpose (MUST), 30 January 1975

[10] Military Specification MIL-S-43915, Shelter Expandable for Medical Unit Self-Contained, Transportable (MUST), 27 December 1974

[11] Military Specification MIL-S-55286A, Shelter Electrical Equipment S-280 ( )/G, 9 March 1973

[12] Military Specification MIL-S-81030D, Shelter, Air Transportable, Aircraft Support, 12 March 1974

[13] Military Specification MIL-C-52661A, Containers, Cargo, 25 June 1974

[14] Military Specification MIL-C-52788 Container, Refrigerated, 8 Ft X 8 Ft X 20 Ft, Insulated, 14 May 1974

Load Requirement	DOCUMENT								3/1 Prototype Cont Shelter 6.1 m
	ANSI MH 5.1 & 5.1.1	MIL-C-[illegible] 6.1 m Cargo Container	MIL-C-[illegible] 6.1 m Refrig Container	MIL-S-[illegible] 6.1 m Shelter	MIL-S-[illegible] 3.[illegible] m MUST Shelter	MIL-[illegible]-43911 [illegible] m MUST Shelter	MIL-S-[illegible] 3.[illegible] m Electrical Shelter	MIL-S-81030D 6.1 m Aircraft Shelter	
Stacking	6 high / 1.8 for for 5 min, i.e. 100,800# on each corner	Same as 5.1 except no time limit	Same as 5.1 except repeat with opp. offset & no time limit	None	None	[illegible] high for 2 hours	None	Same as 5.1	IAW 5.1 & 5.1.1
Top Lift	Load to 2.[illegible] / DGW & lift for 5 min	Load to 2 / DGW & lift for 5 min	Same as 5.1	Load to [illegible] / DPL & lift for [illegible] min	Load to [illegible]# minus cont wgt & lift for [illegible] min	Load to [illegible]# minus cont wgt & lift for 30 min	Load to [illegible] / DPL + 2 / cont wgt & lift for [illegible] min	Load to 2 / DGW & lift for 5 min	IAW 5.1 & 5.1.1
Bottom Lift	As above	As above	As above	None	None	None	None	None	IAW 5.1 & 5.1.1
Restraint	DGW / 1.8 in tension & compression	DGW / [illegible] in tension & compression for 1 min	DGW / [illegible] in tension & compression for 1 min	None	None	None	None	Same as 5.1	IAW 5.1 but add 1 min duration applied slowly
Racking	Transverse & Longitudinal Racking at 33,[illegible]#	Same as 5.1 & 1 min duration	Same as 5.1 & 1 min duration	None	None	None	None	None	IAW 5.1 but add 1 min duration slowly
Lashing	Tension & compression at 10 specified loads	None	None	None	None	None	None	None	IAW 5.1 but add 1 min duration applied slowly
End Wall	[illegible] / DPL, uniform load	[illegible] DPL for 1 min	[illegible] DPL for 1 min	None	None	None	None	None	IAW 5.1
Side Wall	As above	[illegible] DPL for 1 min	[illegible] DPL for 1 min	None	None	None	None	None	IAW 5.1
Roof	[illegible]# over 2 ft² also 1.11 / DPL uniform up	[illegible]# over 2 ft for 1 min	[illegible]# over 1 ft for 1 min	[illegible]	None	None	None	[illegible]# over 1 ft², also [illegible] PSF over roof for 30 min	660# over 2 ft²
Railroad Hump	None	None	None	[illegible] impacts at [illegible] MPH	[illegible] impacts at 8.[illegible] MPH	[illegible] impacts at 8.[illegible] MPH	[illegible] impacts at [illegible] MPH	None	[illegible] impacts at 9 MPH
Drop	None	None	None	[illegible]" on concrete, [illegible] flat, [illegible] edge	None	None	[illegible]" on concrete, 1 flat, [illegible] edge	18" on concrete 1 flat, 4 edge	12" on concrete, 2 corner, 2 edge
Truck Transport	None	None	None	[illegible] roads at Aberdeen [illegible]	None	None	1 road at 4 speeds	None	3 roads
Dolly Transport	None	None	None	1 road at Aberdeen [illegible]	[illegible]	[illegible] roads	None	None	3 roads
Towing	None	None	None	None	[illegible] ft	[illegible] ft	3,[illegible] simulated	2,800 ft	600 ft plus 4 turns

Abbreviations:
IAW - In accordance with; DPL - Design payload; cont - Container
DGW - Design gross weight; wgt - weight; PSF - pounds per sq ft

Notes:
Reference data only. For complete test requirements see applicable document.
English units are used to allow rapid comparison with published documents.

Figure 3. Transportation Tests Summary.

Only the 300-kilogram (660-pound) portion of the ANSI roof load test was selected. The 1.11 times the design payload in the upward direction portion of the test is intended for containers with multi-unit resilient lading which could bear against the roof in air shipment and is not representative of the 3/1 shelter.

The railroad hump, truck transport, dolly transport and towing tests are a blend of the other tests listed and appear to be a realistic compromise.

The drop test is based on Federal Test Method Standard No. 101B,[15] Methods 5005, 5007 and 5008 and therefore the common free-fall, flat-drop test is not included. The one 46-cm (18-inch) flat and four 46-cm edge drops normally extracted from MIL-STD-810C[16] for container tests were intentionally not used because the standard expressly states that they are not representative of the logistics shipping environment experienced by shipping containers.

The ANSI floor strength test which includes operation of a forklift truck on the floor and also a uniform static load on the floor is not listed because these conditions apply to a container primarily intended to transport cargo and are not applicable to the 3/1 shelter.

A detailed test plan was prepared to subject the 3/1 shelter to this composite transportation environment and is included as the Appendix to this report.

INSTRUMENTATION AND DATA ACQUISITION SYSTEM

The shelter was instrumented with seven accelerometers, twenty single-element strain gages and seven strain gage rosettes as shown in Figures 4 through 7. Forty-eight channels of information were therefore available, although all sensors could not be activated in all tests.

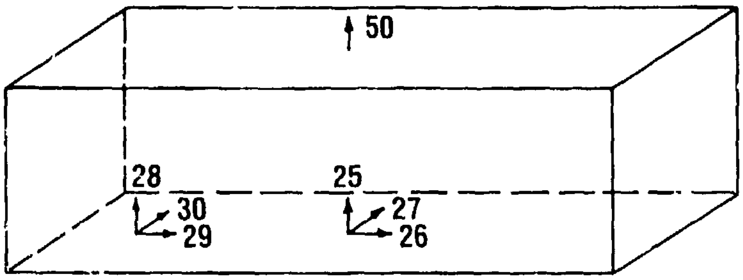
The accelerometers were CEC/Bell & Howell type 4-202-0001 linear unbonded strain gage bidirectional models with four-active-arm spring-type sensing elements. The sensors mounted in the vertical, longitudinal and transverse directions had ranges and approximate natural frequencies of: ± 15 g, 530 Hz; ± 10 g, 400 Hz; and ± 5 g, 300 Hz, respectively. The floor-mounted accelerometers were positioned in a tri-axial configuration.

The single-element strain gages were BLH type FAE-25-35-S13EL. The rosettes were 60° planar BLH type FAER-50D-35-S13EL. Bridge completion networks, BLH type

[15] Federal Test Method Standard No. 101B, Preservation, Packaging, and Packing Materials: Test Procedures, January 15, 1969

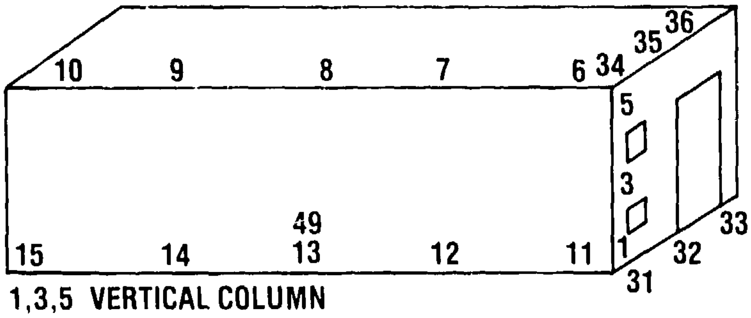
[16] Military Standard 810C, Environmental Test Methods, 10 May 1975

ACCELEROMETERS



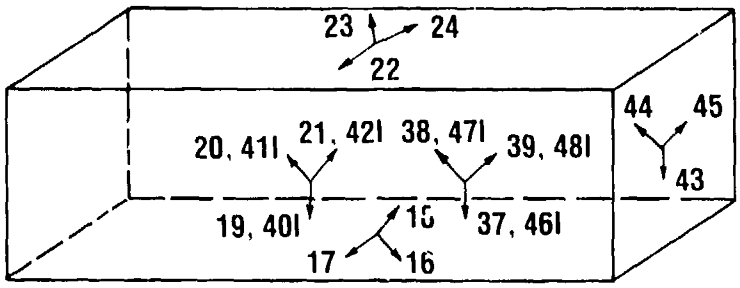
25 FLOOR, CENTER, VERTICAL
26 FLOOR, CENTER, LONGITUDINAL
27 FLOOR, CENTER, TRANSVERSE
28 FLOOR, QUARTER, VERTICAL
29 FLOOR, QUARTER, LONGITUDINAL
30 FLOOR, QUARTER, TRANSVERSE
50 ROOF, CENTER, VERTICAL

SINGLE AXIS GAGES



1,3,5 VERTICAL COLUMN
6-10 LONGITUDINAL, TOP
11-15 LONGITUDINAL, BOTTOM
31-33 TRANSVERSE, BOTTOM
34-36 TRANSVERSE, TOP
49 LONGITUDINAL "I" FLANGE

ROSETTE GAGES



16-18 FLOOR, CENTER, INTERNAL
19-21 SIDEWALL, CENTER, EXTERNAL
22-24 ROOF, CENTER, EXTERNAL
37-39 SIDEWALL, QUARTER, EXTERNAL
40-42 SIDEWALL, CENTER, INTERNAL
43-45 ENDWALL, EXTERNAL
46-48 SIDEWALL, QUARTER, INTERNAL

Figure 4. Sensor Layout Sketch.

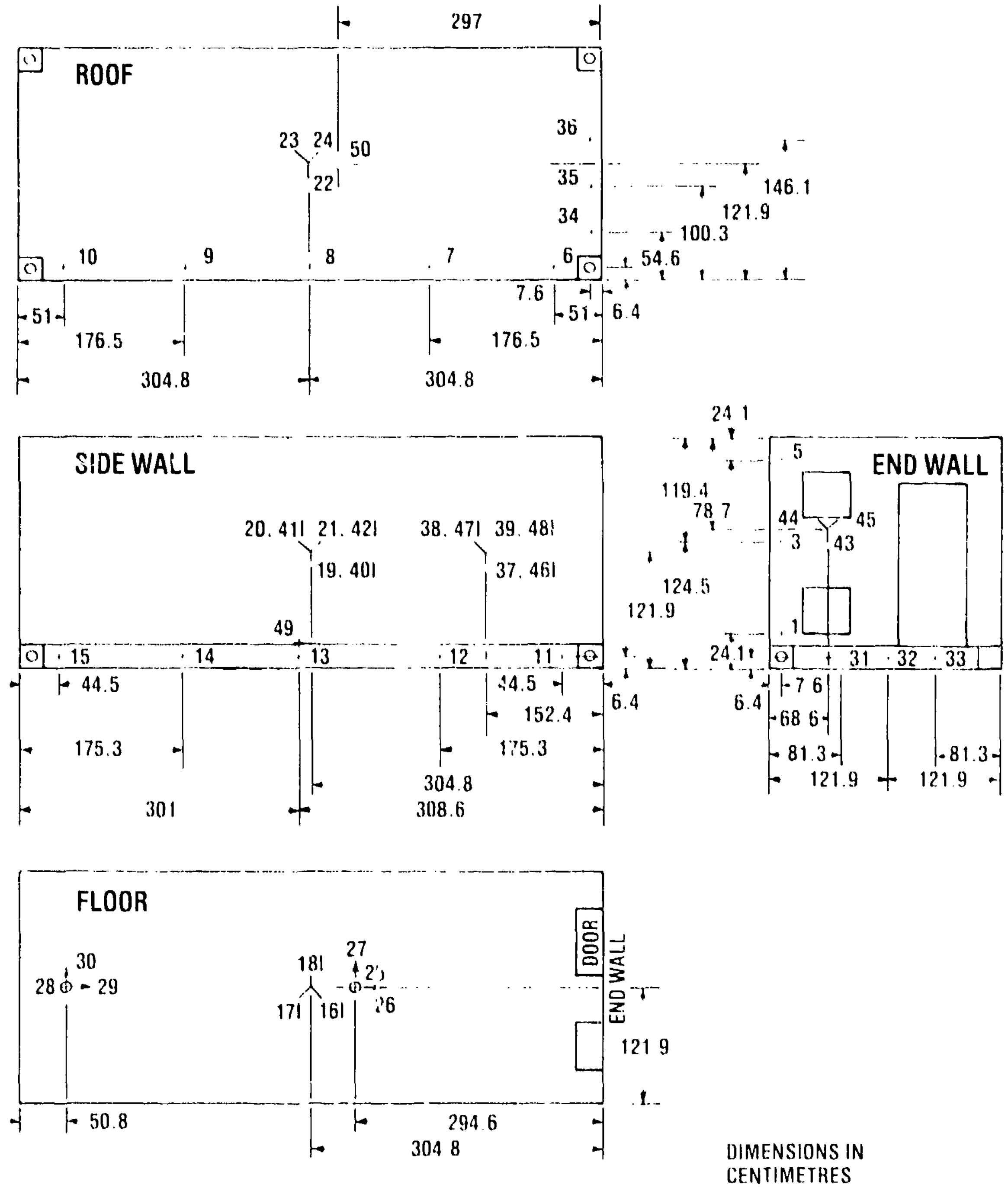


Figure 5. Detailed Sensor Layout.

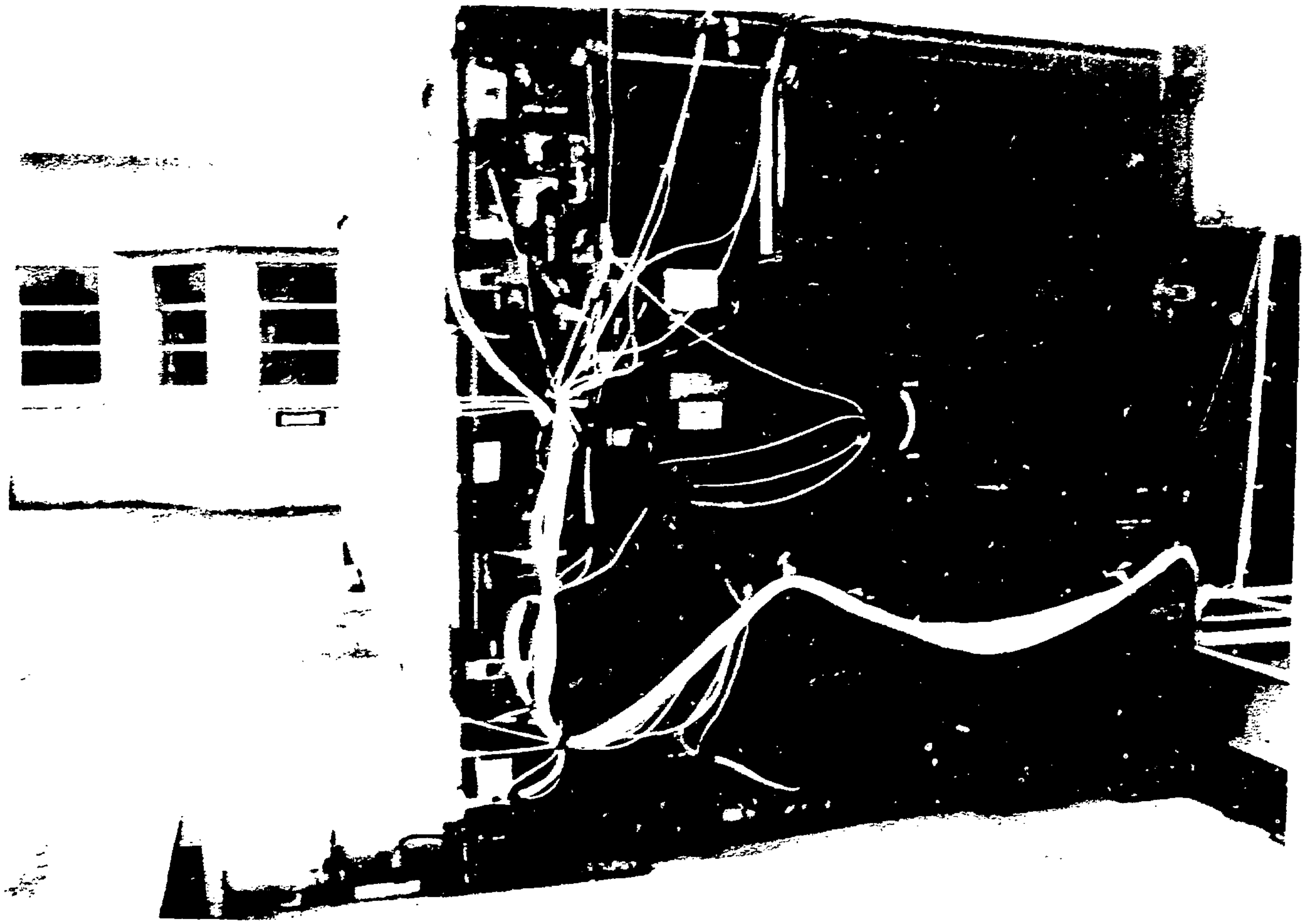


Figure 6. Instrumented End Wall. Several strain gage locations, covered with aluminum foil, and the associated wiring are apparent. The load transducer and hydraulic jack are also visible next to the lower left ISO fitting.

Figure 7. Instrumented Roof. The shelter is turned over and resting on a side wall so that the roof is visible. One strain gage rosette is mounted on the center of the roof. Five gages are mounted along the longitudinal extrusion. Three gages are mounted along the transverse extrusion.

BCNA-2-QB-350, were used with each gage to form a full four-arm Wheatstone bridge and were mounted on the shelter adjacent to each measuring strain gage. Each active gage was mounted with Eastman 910 adhesive and protected with a weatherproof barrier material and aluminum foil.

The magnitude of the tensile and compressive loads was monitored with either a BLH Model T2P1-50K or a Transducer Inc. Model BTC-FF-42-CS-100K general purpose load cell.

The signal conditioning and recording equipment consisted of two Honeywell Model 82-6 and four CEC Model 8-108 bridge balances, an appropriate number of CEC type 7 315 galvanometers and two Bell & Howell Model 5-134 light beam recording oscillographs. The galvanometers have an undamped natural frequency of one-hundred Hertz and a flat frequency range of zero to sixty Hertz.

EXPERIMENTAL PROCEDURE

The container was chained from the top corner fittings to a level-deck, low-bed, semi-trailer for the truck transport test. The instrumentation was placed inside the container and a portable generator was used to power the oscillographs. Steel weights were used as ballast to simulate a uniform payload. The cross-country traverse was conducted over open fields.

The ISO static load tests could not be duplicated exactly because the specialized loading fixtures required to conduct the tests in a rapid manner were not available locally and tests of just one unit did not justify fabricating them. Simpler, less precise methods of applying the loads, however, were improvised. These methods required that the container be rotated to position it for various tests and prohibited the use of a uniform floor load in the vertical stacking test. Although these loading techniques were not the most efficient, the results obtained were completely adequate for the purposes of the study.

The container was positioned on top of a large concrete platform into which various hold-down devices had been positioned to restrain the shelter during loadings. The compressive loads were applied with a 445-kilonewton (50-ton) hydraulic jack and the tensile loads were applied through an appropriate cabling setup with a 356-kilonewton (40-ton) portable crane. Figure 8 is an overview of the test setup showing the concrete platform, the instrumented 3/1 shelter, the portable crane, and in the left center, a second shelter (with a red cross) used to house the instrumentation.

Figure 8. Test Setup. From right to left: portable crane, concrete pad, 3/1 prototype shelter, and medical shelter used to house instrumentation.

RESULTS

The results are presented in the chronological order in which the tests were conducted because, as noted later time and damage prevented all the tests from being completed. Strain is presented as microstrain, tension positive, compression negative. Frequency is in Hertz, and accelerations are double amplitude, peak to peak.

Top and Bottom Lift

The top and bottom lift tests require that the shelter, loaded with a payload of 15,445 kilograms (34,050 pounds) be lifted by the top or bottom corner fittings. During preparation for the over the road tests the shelter was used to transport 6,804 kilograms (15,000 pounds) of steel ballast. While the loaded shelter was being lifted by the top corner fittings, the floor deflected excessively and popped most of the rivets along the hinge line between the fixed and folding floors. It was obvious from the premature failure that the shelter could not meet the ISO lift requirements and these two tests were cancelled to preclude further damage.

Truck Transport and Towing

The shelter was loaded to a total gross mass of 6,804 kilograms (15,000 pounds) and seven accelerometers and eight strain gage channels were activated during the truck transport and, towing tests. The data collected are presented in Tables 1 and 2. The strain gage instrumentation failed during the cross-country traverse and no data are available for that portion.

The tabulated quantities are high and low values, with occasional spikes noted, summarized from lengthy oscillograms for the courses covered. Accelerations during the tow tests were negligible. During the paved highway, gravel road and cross country runs, the three maximum accelerations were recorded in the vertical plane in decreasing order by the sensors mounted on the floor near the rear of the flatbed, on the center of the roof, and then on the center of the floor. During the paved highway transport the oscillograms indicated several spikes of 100 g's at 100 Hertz. These data are noted but are to be ignored because: (1) the amplitude (100 g's) exceeds the accelerometer capability; (2) the vibration frequency (100 Hz) is the same as the natural frequency of the galvanometer (an undesirable condition) and also exceeds the flat frequency range of the galvanometers, and (3) the 100 g amplitude is not consistent with the gravel road, cross country or published data. The 2.5 and 9-g spikes noted during gravel road and towing tests are also suspect because of the frequency reasons. Figure 9 shows the shelter mounted on the flatbed during the paved highway traverse. The shelter did not sustain any damage during truck transport.

The only significant transportation strains recorded were during the towing tests. These occurred while the shelter was being towed in the direction away from the instrumented transverse member. When the shelter was towed in the opposite direction,

Table 1

Truck/Tow Transport Acceleration Data[a]
A = Amplitude in g's (Peak to Peak)
f = Frequency in Hertz

Sensor	Paved Highway		Gravel Road		Tow		Cross Country	
	A	f	A	f	A	f	A	f
25	0.4 0.6	35 20	1.1 0.8	4 30	0 0.1	0 100	0.6 1.3	2 3
26	0.2 0.3	30 30	0.4 –	40 –	0 0.1	0 100	Random 0.2 Spikes	
27	0.2 0.5	50 20	0.2 0.4	45 25	0 0.1	0 100	0.3 0.2	2 0
28	1.4 0.6	4 7[b]	2.1 0.9	4 5[d]	0 0.3	0 100	0.7 2.4	5 4
29	0.3 0.4	30 7 + 30[c]	0.3 –	30 –	0 0.3	0 0	0.3 0.7	4 3
30	0.2 0.3	25 20	0.4 0.3	25 45	0 0.1	0 50	0.1 –	0 –
50	0.5 0.9	35 30	0.4 1.6	40[e] 4 + 30	0.1 0.3	70[f] 75	0.7 1.5	4 5

NOTES:

[a]The acceleration and frequencies tabulated are representative values which envelope the recorded data.

[b]100 g spikes at 100 Hz, (exceeds accelerometer range).

[c]7Hz base wave carrying 30 Hz wave.

[d]9g spikes at 100 Hz (poor frequency match).

[e]4 Hz base wave carrying 30 Hz wave.

[f]2.5 g spike at 100 Hz (poor frequency match).

Table 2

Truck/Tow Transport Microstrain Data*
A = Amplitude in Microstrain (Peak to Peak)
f = Frequency in Hertz

Sensor	Paved Highway		Gravel Road		Tow		Cross Country	
	A	f	A	f	A	f	A	f
11	180	35	0	0	0	0		
	267	35	360	30	–	–	No Data Available	
12	0	0	90	3	180	0		
	–	–	180	4	390	0		
13	0	0	0	0	90	0		
	–	–	–	–	450	0		
14	0	0	0	0	0	0		
	–	–	–	–	–	–		
15	0	0	0	0	0	0		
	–	–	–	–	267	0		
31	0	0	0	0	980	0		
	–	–	–	–	360	0		
32	No Data				1600	0		
					620	0		
33	180	35	180	35	360	0		
	–	–	–	–	710	0		

NOTES:

*The strains and frequencies tabulated are representative values which envelope the recorded data.

Figure 9. Paved Highway Transport. Instrumented shelter positioned on flatbed undergoing paved highway transport test.

gages 31, 32, and 33 were destroyed by the plowed-up dirt. The shelter could not be towed as planned over a rough plowed surface because the base of the end wall dug into the ground. The tow tests were therefore conducted over a hard packed gravel surface, not without some difficulty and plowing action as shown in Figures 10 and 11. Three transverse floor support channels located under the floor were bent and pulled loose during the tow tests and had to be repaired before static load testing.

Roof Load

As expected, no appreciable strains were recorded during the 300-kilogram (660-pound) static load roof test.

Lower Longitudinal Restraint and Lashing (Compression)

The lower longitudinal restraint test requires that the container, loaded to a total mass of 6,804 kilograms (15,000 pounds), and secured through the bottom aperture of a bottom corner fitting, have a force of 60 kilonewtons (13,500 pounds) applied longitudinally through the bottom aperture of the bottom corner fitting at the opposite end of the container. The lower longitudinal lashing test is similar but requires that a longitudinal force of 150 kilonewtons (33,600 pounds) be applied normal to the lower corner fitting of an empty container.

The lower longitudinal, compressive restraint and lashing tests were conducted simultaneously, but not in strict accordance with the ISO test plan. The shelter contained a payload. The force was applied normal to the corner fittings and gradually increased from zero to 150 kilonewtons. Therefore, the requirements of both tests were basically accomplished, but not exactly, by the application of one load.

Oscillographic records of strain and load were generated continuously from zero to peak load during the test. A summary of these oscillograms at several discrete load increments selected to give a representative profile is presented in Table 3. A plot of the table strain versus load data, for the most active gages, is presented in Figure 12.

No shelter damage was sustained during the test.

Lower Longitudinal Restraint (Tension)

The 60-kilonewton lower longitudinal tensile load was applied in accordance with the test plan, except the point of application was through the corner fitting side aperture, not the bottom aperture. The recorded strains are summarized in Table 4 and plotted in Figure 13. No shelter damage was noted after the test.

Upper Longitudinal Lashing (Tension)

The 100-kilonewton (22,400-pound) upper longitudinal load was applied in accordance with the test plan except the container was positioned on its side, and raised slightly

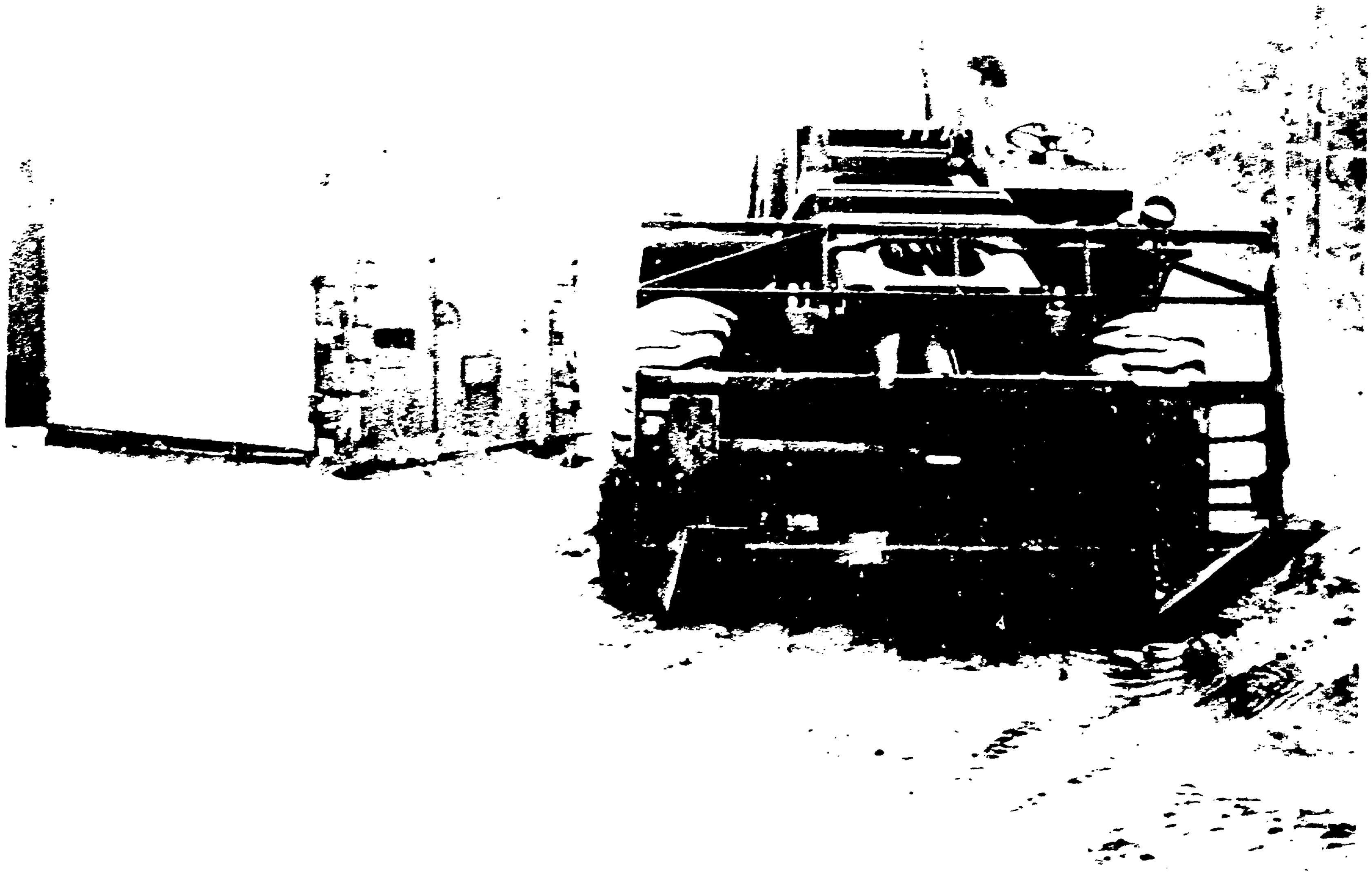


Figure 10. Tow Test. Shelter being towed over hardpacked gravel surface by forklift.

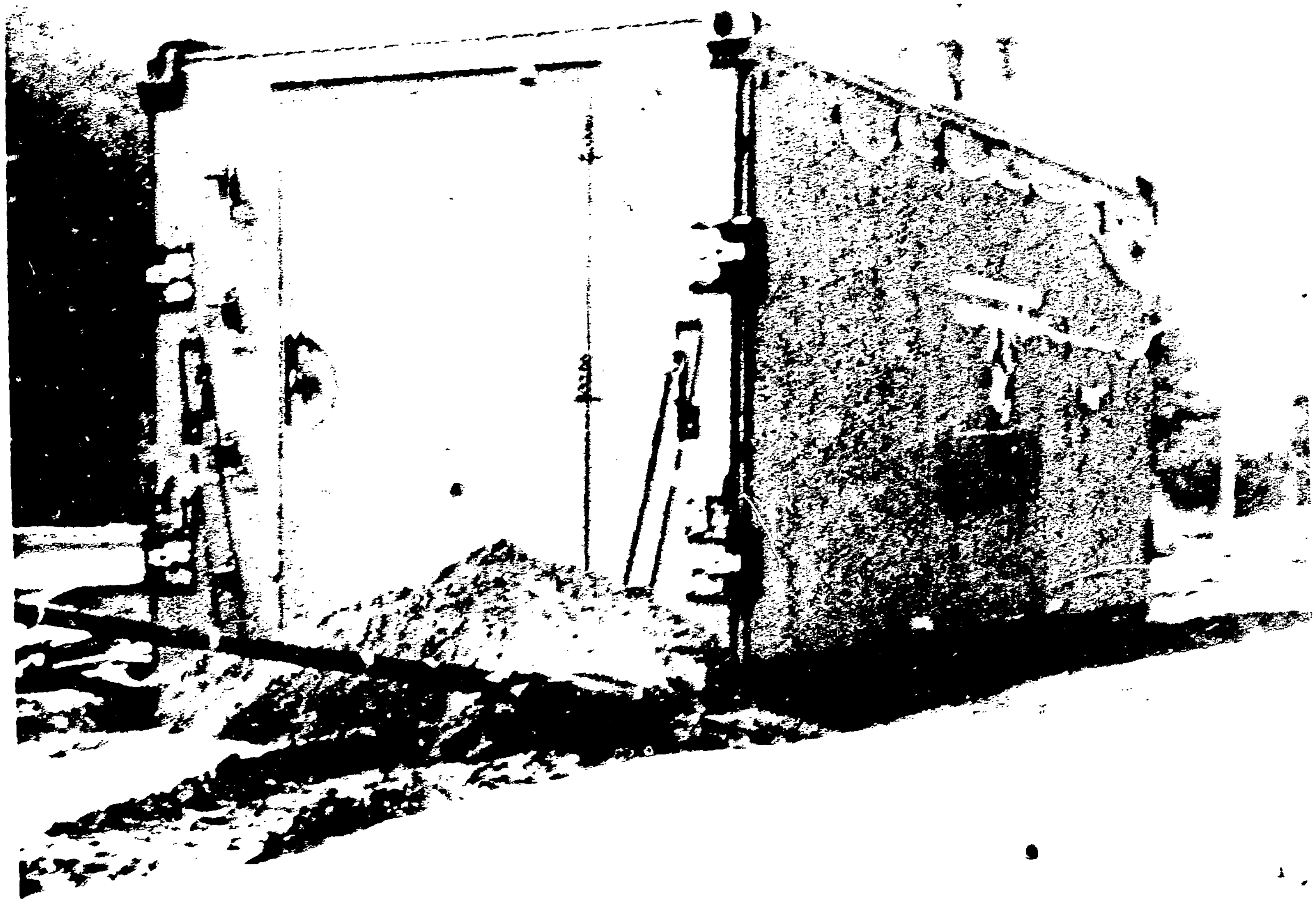


Figure 11. Tow Test. Plowing action by leading end of shelter evident. Considerable soil buildup also occurred underneath shelter.

Table 3

Lower Longitudinal Restraint and Lashing (Compression) Microstrain Data*

Strain Gage	Load (Kilonewtons) 44.5	89.0	149.5	155.7
11	−265	−560	−1020	−1070
12	−125	−350	−615	−630
13	−125	−350	−700	−720
14	−210	−385	−665	−685
15	−405	−840	−1335	−1350
16	0	0	0	0
17	−20	−55	−90	−105
18	−55	−90	−160	−175
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0
32	+20	+35	+70	+105
37	0	0	0	0
38	0	0	0	0
39	0	0	0	0
46	−105	−300	−545	−560

NOTES:

*Tensile values positive.

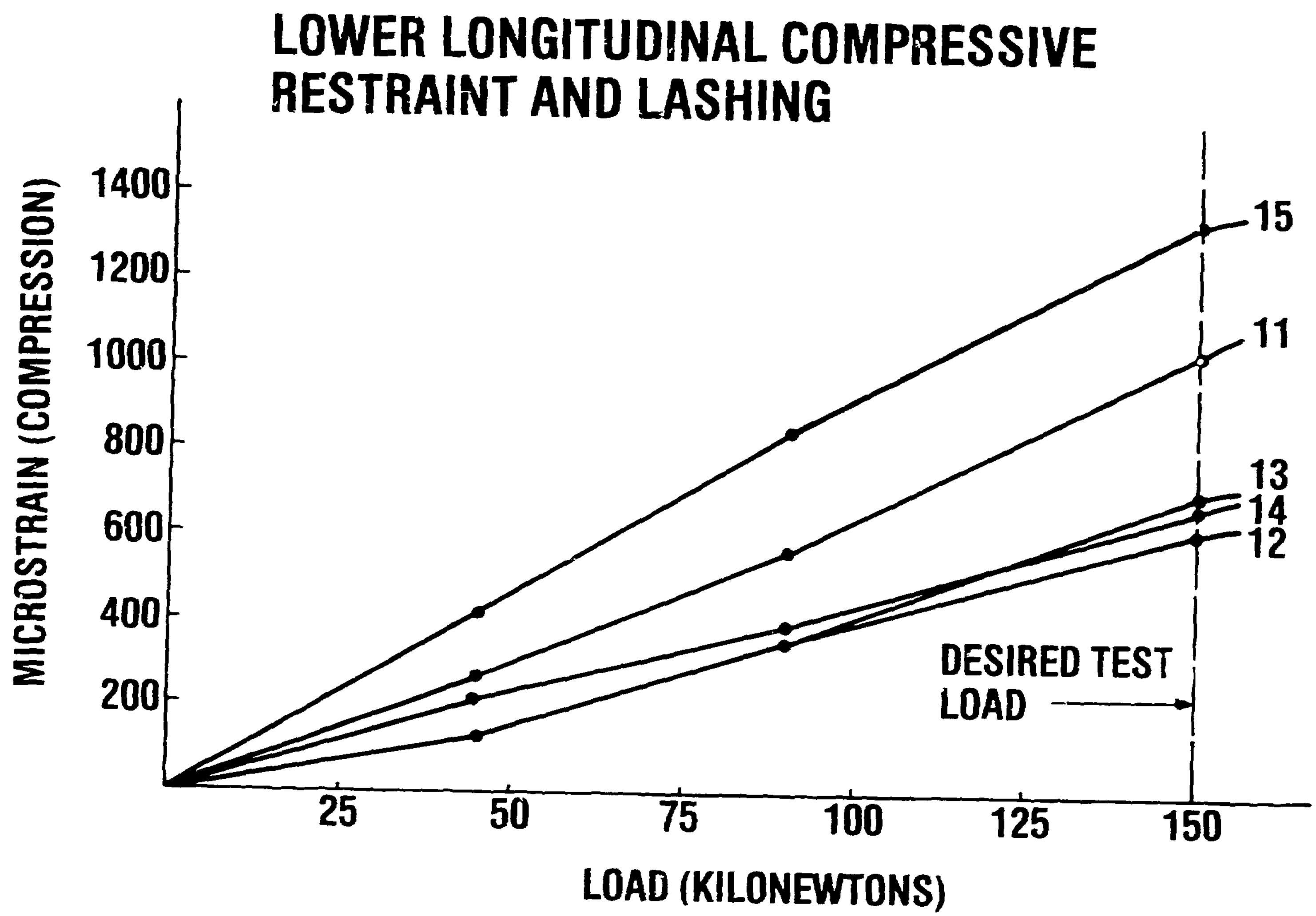


Figure 12. Lower Longitudinal Restraint and Lashing (Compression) Strain Profile. Strain versus load for the five most active gages (11–15).

Table 4

Lower Longitudinal Restraint (Tension)
Microstrain Data*

Strain Gage	Load (Kilonewtons) 22.2	44.5	60.0
11	+335	+615	+755
12	+210	+405	+525
13	+175	+350	+475
14	+230	+350	+510
15	+385	+580	+755
19	0	0	0
20	+20	+35	+55
21	−20	−20	−35
31	+35	+90	+125
32	0	−35	−55
33	0	−20	−20
37	0	0	0
38	0	0	0
39	0	0	0

NOTES:

*Tensile values positive.

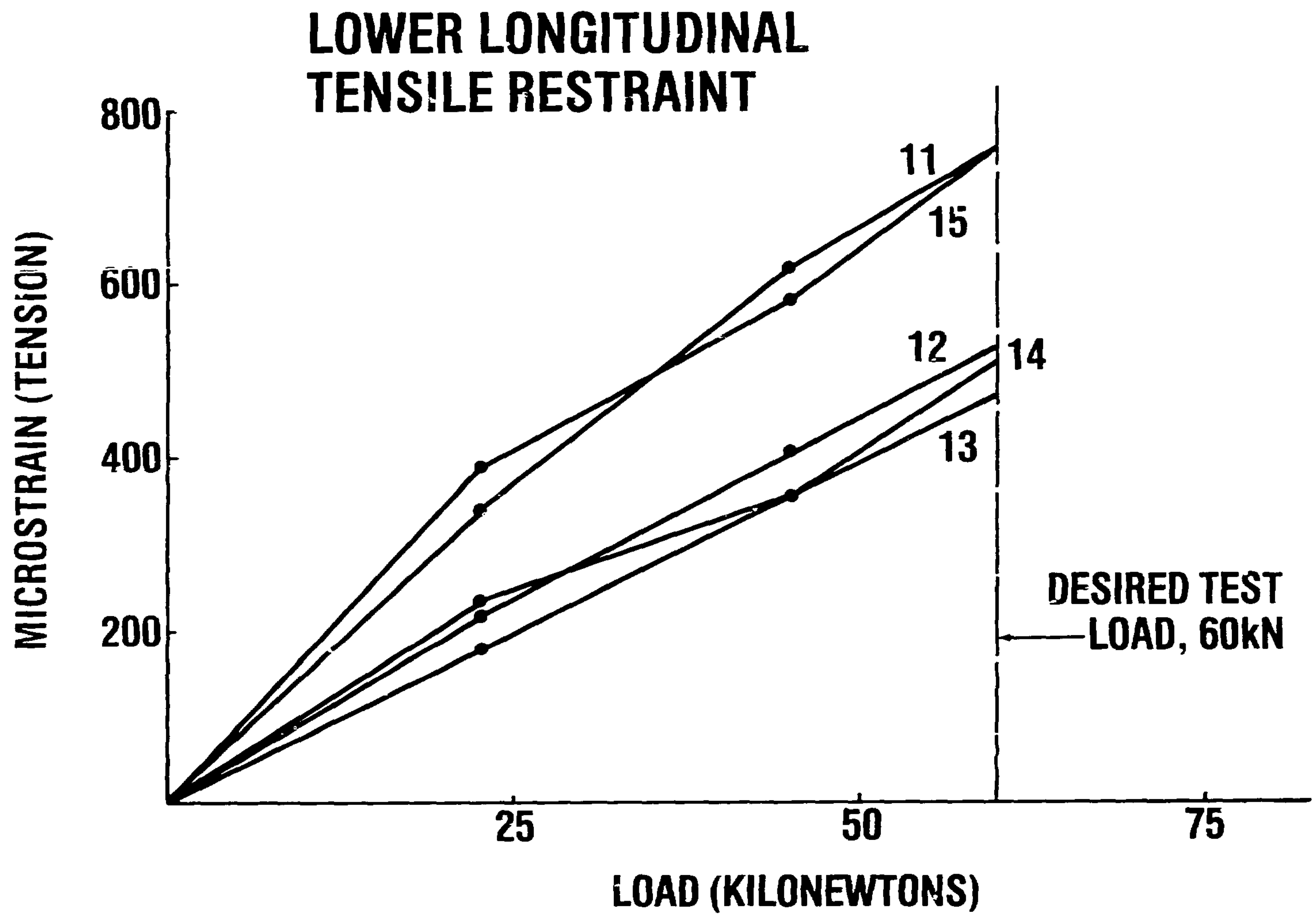


Figure 13. Lower Longitudinal Restraint (Tension) Strain Profile. Strain versus load for five most active gages (11–15).

off the ground with pads as shown in Figure 14 to facilitate load application. The data generated are presented in Table 5 and Figure 15. No shelter damage was noted during the test.

Vertical Column Lashing (Compression)

The compressive vertical column lashing test was conducted twice in accordance with the test plan except the container was positioned on its side to facilitate load application and the desired load of 300 kilonewtons (67,200 pounds) was not attained because the load cell indication was misread and the load was terminated short of the specified value. The data are presented in Table 6 and Figure 16. On the first run, one or possibly more bolts securing the upper fitting to the vertical column failed. After the second run, all six bolts definitely had been sheared off. Figure 17 shows the upper corner fittings with four bolts completely sheared off and two bolts broken but jammed in place. Post-failure inspection disclosed that the fitting had not been mounted snug against the vertical column. A gap of approximately 6 mm had existed and therefore most of the compressive load was transferred from the fitting to the column through the six bolts and hence the premature failure.

Stacking

The stacking test was attempted after completion of the compressive vertical column lashing test without replacing the bolts which had secured the upper fitting. Although the six bolts no longer secured the fitting, the fitting now rested snugly on the vertical column and provided a proper load path for the compressive load. The lashing test had disclosed a design deficiency in mounting of the fitting, and it was reasoned that even with the damaged fitting, the greater stacking load could still be used as a valid test of the vertical column.

The container was positioned for stacking in the same manner as for vertical column lashing, on its side with no payload. The stacking load was offset toward the center of the container roof according to the test plan. The stacking test was terminated at 300 kilonewtons, short of the specified 448 kilonewton test load, to prevent further damage to the shelter, as the damaged fitting was rotating inward and the vertical column was buckling under the load. The strain data generated are presented in Table 7 and Figure 18.

Lower Transverse Lashing (Compression)

The 150 kilonewton lower transverse compressive lashing load was applied in accordance with the test plan. No shelter damage was noted. The data are presented in Table 8 and Figure 19.

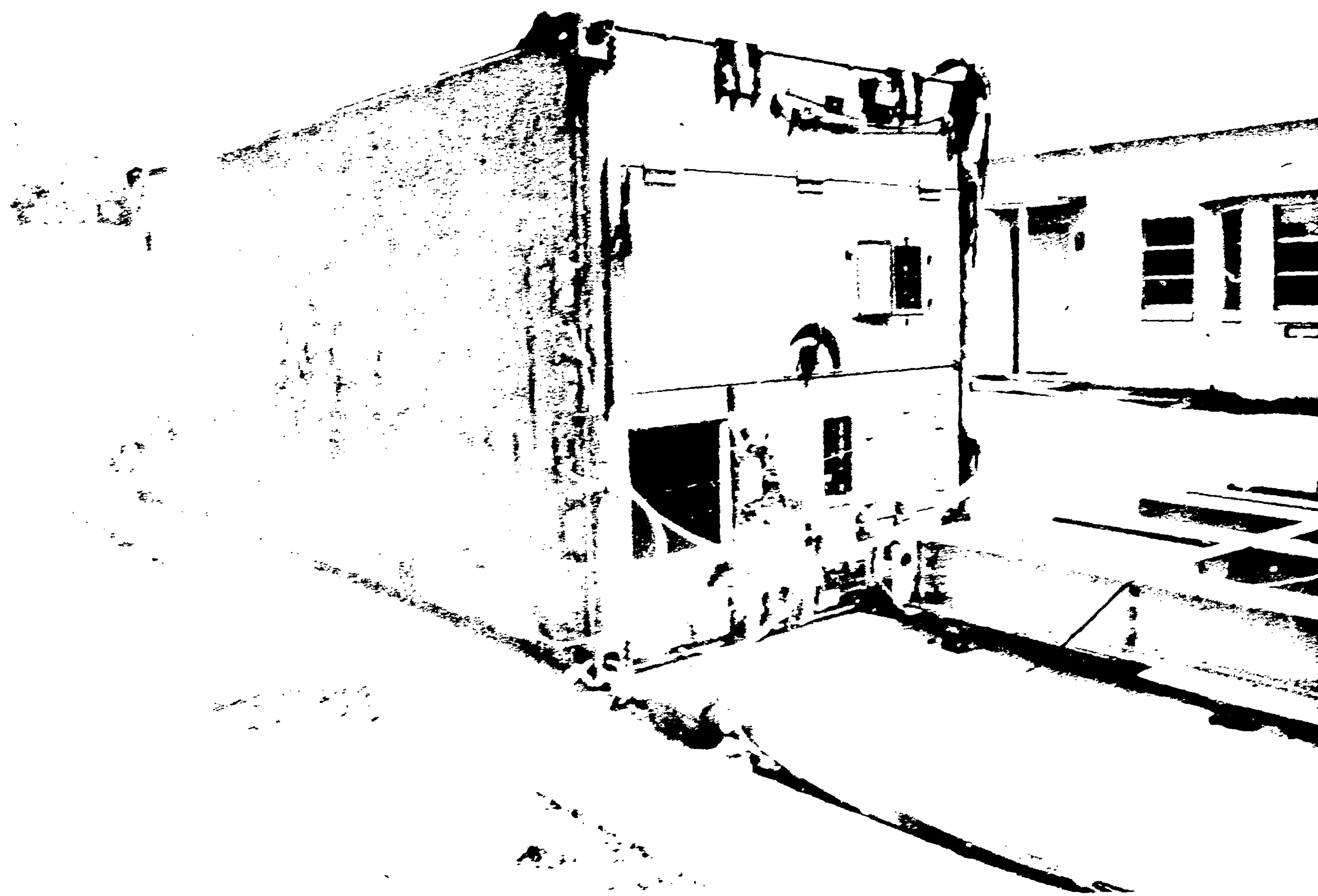


Figure 14. Upper Longitudinal Lashing Test. Shelter positioned on its side for tension test. Load to be applied at far left corner. Shelter restrained at bottom front left corner by nylon webbing. Load cell positioned between fitting and webbing.

Table 5

Upper Longitudinal Lashing (Tension) Microstrain Data[a]

Strain Gage	Load (Kilonewtons) 22.2	44.5	66.7[b]	89.0	100
1	0	0	0	0	0
3	−20	−55	−55	−70	−70
5	−60	−105	−140	−160	−175
6	+230	+510	+755	+1020	+1135
7	+95	+175	+280	+370	+430
8[c]	0	0	0	0	0
9	+105	+185	+280	+360	+415
10	+325	+640	+880	+1285	+1450
11	0	+45	+55	+55	+70
13	0	0	0	0	0
14	0	+10	0	+10	+10
15	0	+25	+35	+45	+45
19	0	−10	0	−10	−10
20	0	+20	+55	+95	+95
21	0	0	0	0	0
22	0	0	0	0	0
23	0	0	0	+10	+10
24	0	0	0	0	0
37	0	0	0	0	0
38	+10	+25	+55	+60	+70
39	0	−10	0	−35	−35
40	0	0	0	0	0
41[d]	+20	+20	–	–	–
42	0	0	0	0	0
46	0	0	0	0	0
47	0	0	0	0	0
48	0	0	0	0	0
49	0	0	0	0	0

NOTES:

[a]Tensile values positive.

[b]Data is average of two runs except at 66.7 kN which is one run only.

[c]Gage 8 data are questionable.

[d]Gage 41 defective.

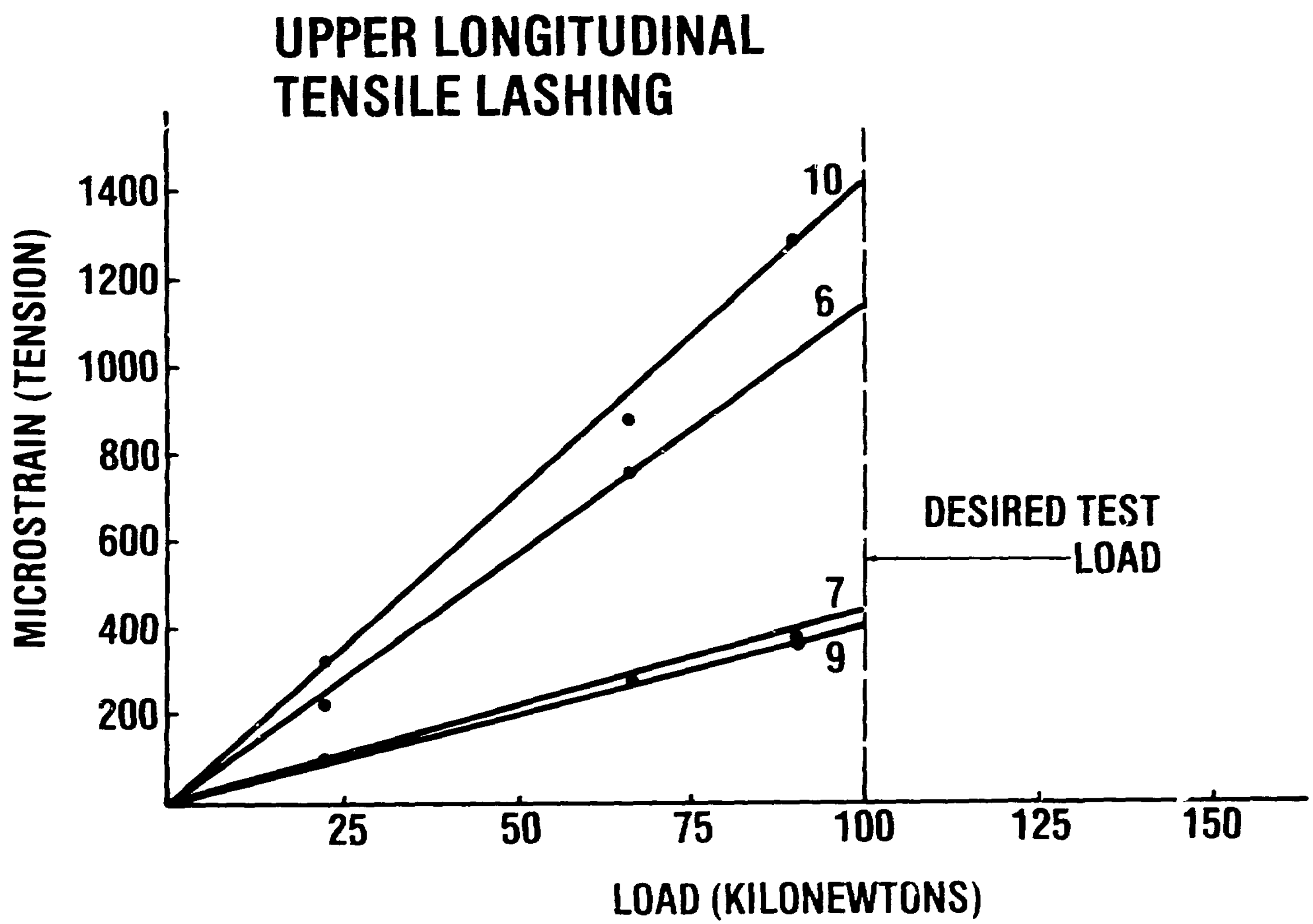


Figure 15. Upper longitudinal lashing (Tension) Strain Profile. Strain versus load for four most active gages (6, 7, 9, 10).

Table 6

Vertical Column Lashing (Compression) Microstrain Data[a,b]

Strain Gage	Load (Kilonewtons) 44.5	89	133.5	178	222.5	242.9[c,d]
1	−415	e	—	—	—	—
3	−230	−460	−705	−985	−1250	−1355
5	−245	−600	−1010	−1320	−1560	−1635
6	+10	+25	+115	+115	+125	+175
7	+10	+25	+60	+60	+60	+105
8	+10	+10	+25	+10	+20	+50
9	+10	+10	+20	+10	+10	+35
10	+25	+35	+35	+45	+45	+35
11	−20	−80	−150	−150	−195	−230
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
31	+260	+475	+595	+735	+860	+875
32	0	0	0	0	0	0
34	+70	+160	+290	+395	+535	+595
35	0	0	0	0	0	0
37	0	0	0	−20	−20	−20
38	0	0	0	+20	+25	+35
39	0	0	−10	−20	−20	−20
41	0	0	0	0	0	0
43	0	0	0	+20	+10	+20
44	+10	+15	+90	+115	+123	+140
45	−35	−115	−200	−235	−305	−335
48	−10	−20	−20	−20	−35	−35
49	0	0	0	0	0	−20

NOTES:

[a]Tensile values positive.

[b]Six bolts failed during the two test runs.

[c]Data is average of two runs except at 242.9 kN which is from one run only.

[d]Desired value of 300 kN not attained because loading erroneously terminated short of goal.

[e]Oscillograph trace off scale. Data not available.

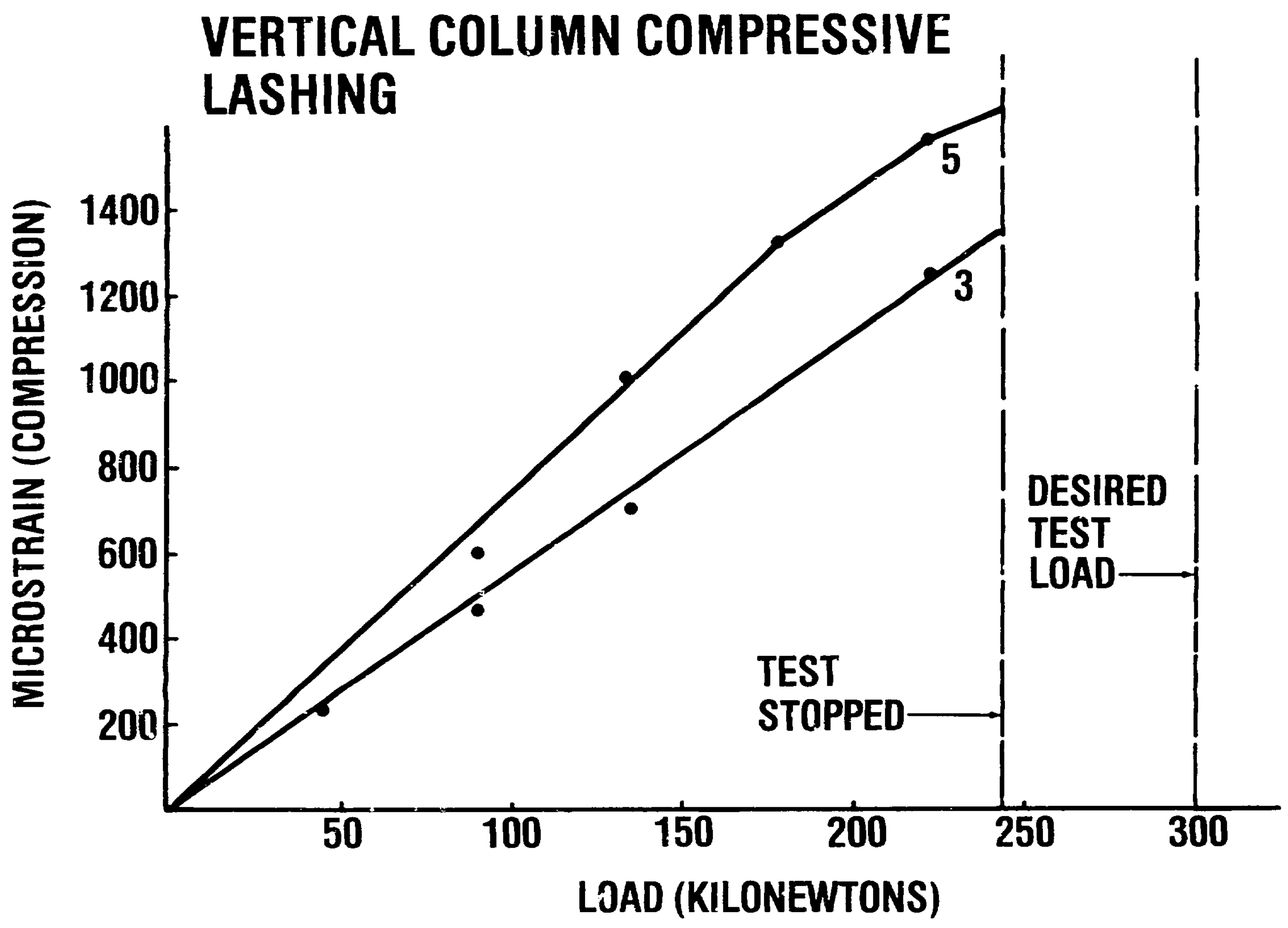


Figure 16. Vertical Column Lashing (Compression) Strain Profile. Strain versus load for two most active gages (3 and 5).

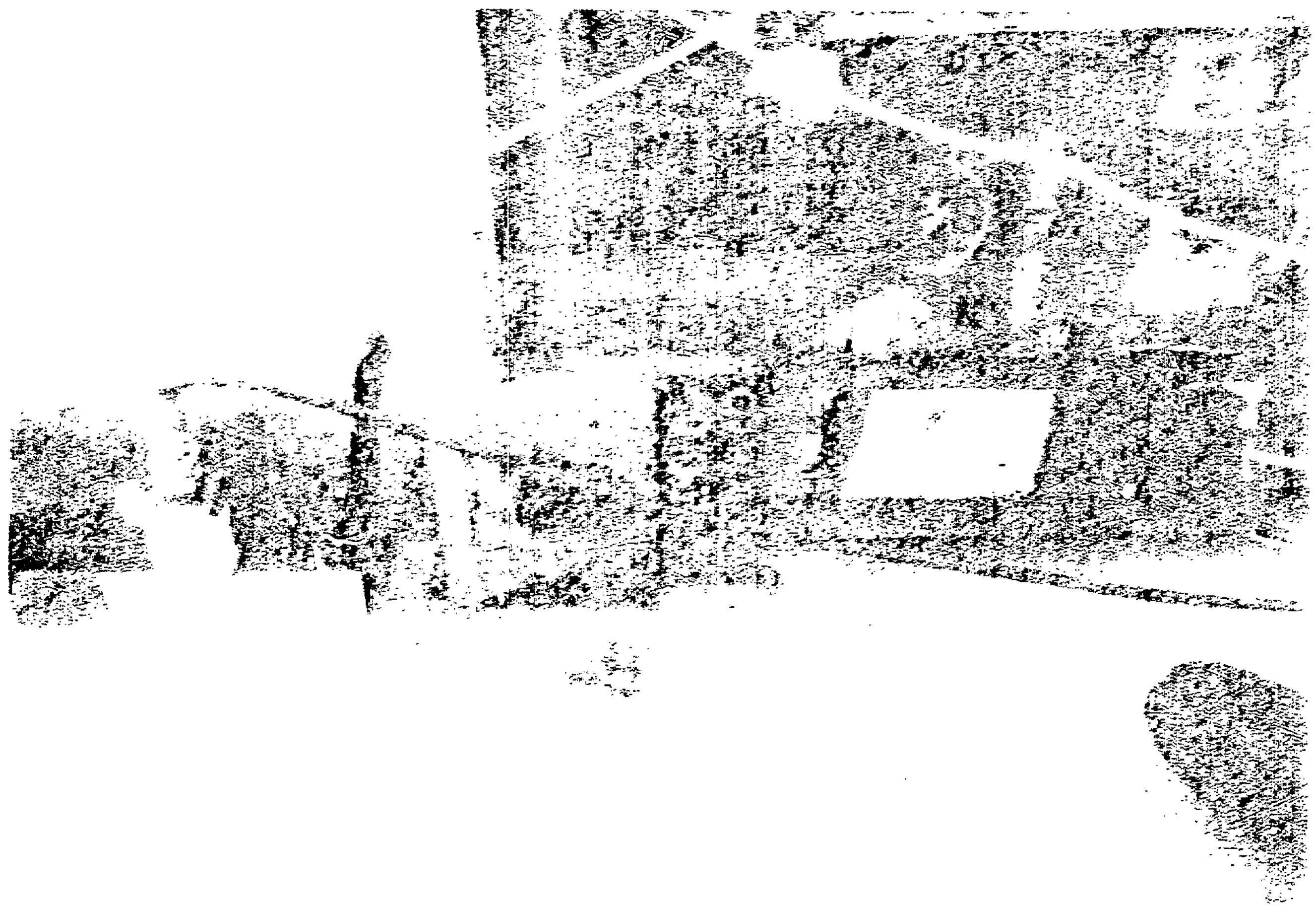


Figure 17. Vertical Column Lashing Failure. Shelter positioned on side. Upper ISO corner fitting visible with four bolt heads completely sheared off and remaining two bolts broken but jammed in place.

Table 7

Stacking Microstrain Data[a,b]

Strain Gage	(Kilonewtons) 44.5	89	133.5	178	222.5	267	300.2[c]
1	300	-510	740	1090	1620	2180	-2550
3	175	-385	-615	880	-1055	-1265	-1410
5[d]							
6							
7	0	0	0	20	0	0	0
8	0	0	0	0	0	0	0
9	+20	+20	0	+20	+20	+20	+20
10	+20	+55	+55	+70	+70	+55	+20
11	0	-20	-65	105	-125	141	195
19	0	0	-20	-20	20	20	0
20	0	0	0	+20	+35	+35	+35
21	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0
24	0	0	0	20	0	0	0
31	+160	+315	+455	+580	+700	+770	+825
32	0	0	0	0	0	0	0
34	+55	+140	+265	+440	+595	+665	+545
35	0	0	0	0	0	0	0
37	0	0	-20	35	-35	35	55
38	0	0	0	+20	+35	+55	+55
39	0	0	0	20	0	20	-20
41	0	0	0	0	0	0	+20
43	0	0	-20	0	0	0	0
44	0	+35	+35	+35	+35	+55	+55
45	0	35	35	55	125	140	175
48	0	0	0	0	0	0	+20
49	0	0	0	0	0	0	20

NOTES:

[a]Tensile values positive.

[b]Stacking test run without repairing previously damaged ISO fitting.

[c]Desired load of 448 kN not attained because column buckling.

[d]Gages 5 and 6 defective.

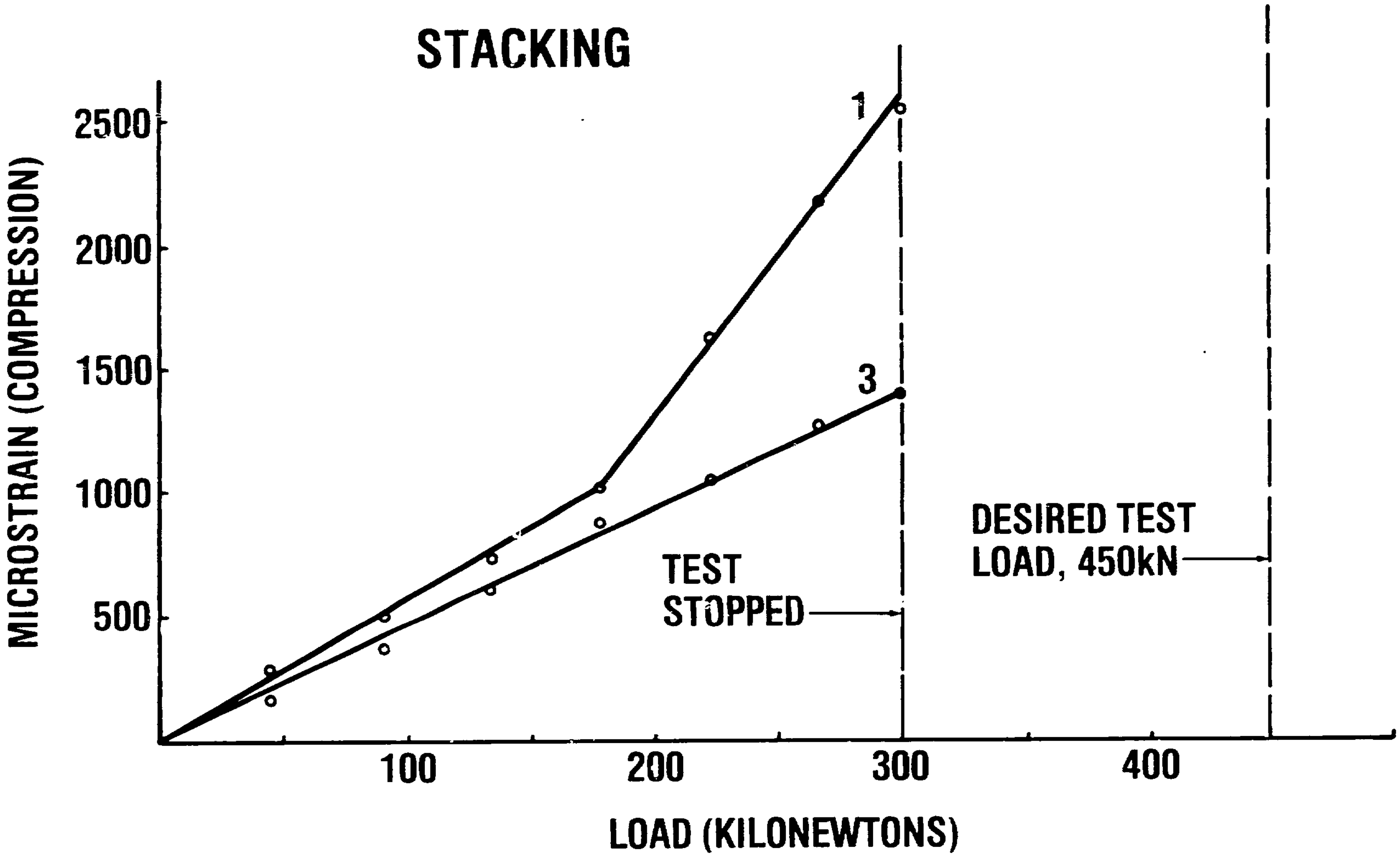


Figure 18. Stacking Strain Profile. Strain versus load for two most active gages (1 and 3).

Table 8

Lower Transverse Lashing (Compression) Microstrain Data[a,b]

Strain Gage	Load (Kilonewtons) 44.5	89	133.5	150
1	+180	+450	+620	+675
3	0	+30	+40	+45
5	0	0	0	0
6	0	0	0	0
7	−5	0	0	0
8	−5	0	+5	0
9	−5	0	+5	0
10	0	0	0	0
11	+20	+45	+70	+70
16	0	0	0	0
17	0	20	−35	35
18	0	−20	−35	35
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0
22	+5	0	0	0
23	+5	−5	5	5
24	0	+5	+5	+5
31	−450	−980	−1390	1565
32	−340	−775	−1090	1220
33	467	−1015	1430	1585
34	0	+10	+25	+15
35	-			
36	+5	+5	+25	+25
37	0	+5	+5	+10
38	0	+5	+5	+5
39	0	0	+5	+5
43	0	+5	+5	0
44	−5	−30	45	45
45	+5	+25	+40	+40
49	0	0	0	0

NOTES:

[a]Tensile values positive.

[b]Data are average of three runs except 16/17/18 one run and 19/20/21 two runs.

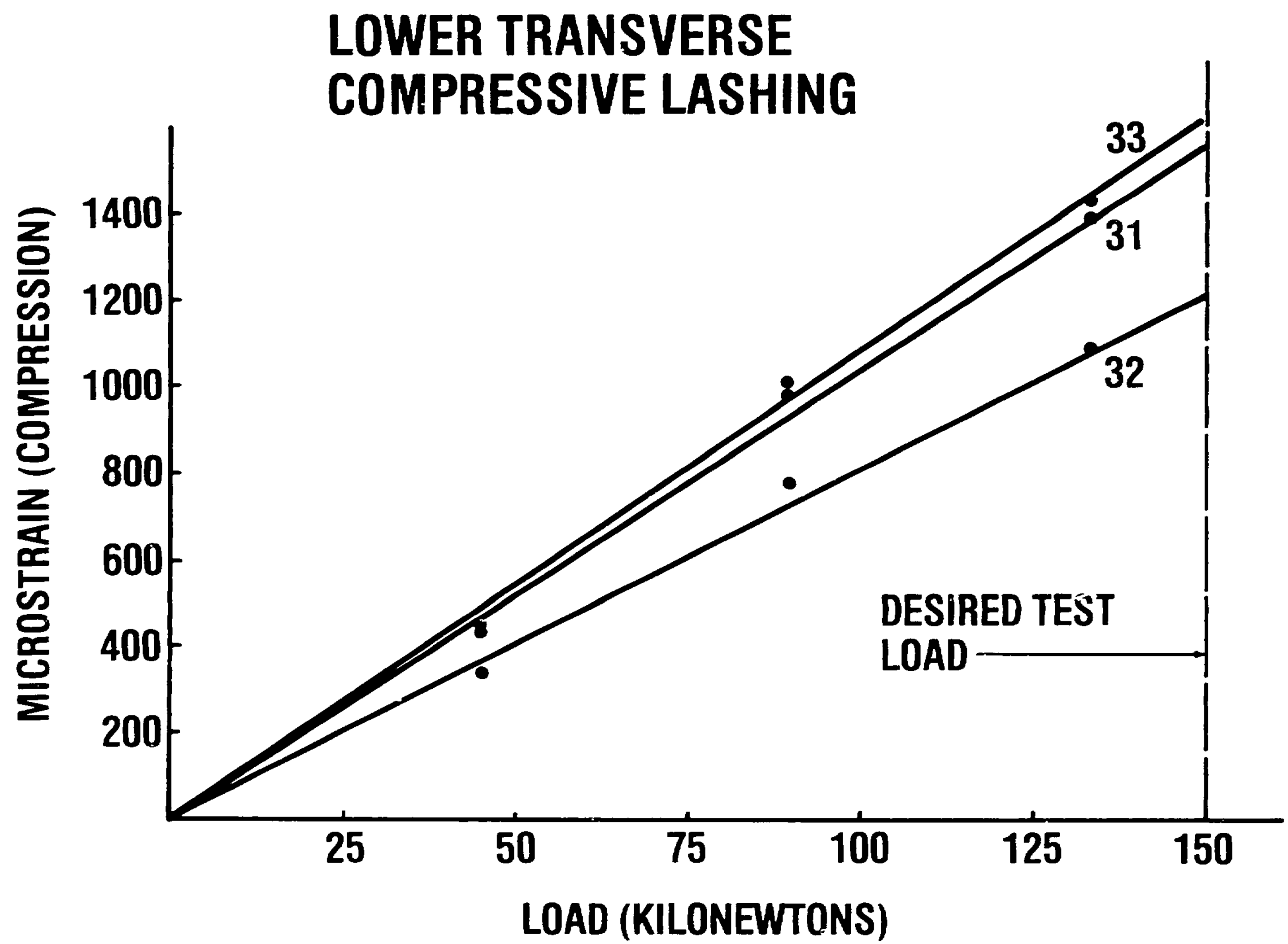


Figure 19. Lower Transverse Lashing (Compression) Strain Profile. Strain versus load for three most active gages (31, 32, 33).

Lower Transverse Lashing (Tension)

The shelter was positioned for the 150-kilonewton lower transverse lashing tensile load according to the test plan. At a load level of 59 kilonewtons the connecting bracket between the ISO fitting and the lower transverse member suddenly fractured, the end wall was ripped apart from the base to the roof, the longitudinal I beam bent, strain gages and wiring were destroyed, and the test was terminated. The data collected up to failure are presented in Table 9 and Figure 20. Figure 21 shows the end wall failure. The tensile load was applied at the lower left fitting. The end panel split to the right of the extruded vertical column. The puddle visible in the lower left of the figure behind the fitting and around the plywood sheet was formed by trapped water in the end wall panel which was released when the wall split. Figure 22 shows the connecting bracket failure.

DISCUSSION

After the transverse lashing failure, the end wall was replaced, the damaged areas were repaired and all the ISO fittings to shelter connections were reinforced. No further testing was possible, however, because manpower shortages, structural failures, and weather had delayed the test program and the prototype shelter was now committed to the Surgeon General for evaluation as an operat room.

The racking, end/side wall, railroad hump, drop, dolly transport and portions of the lashing tests were not completed. Experimental strain data from all of these tests would have been valuable for comparison with the finite element analysis. Results of the tests that were completed, however, indicated that with the reinforced ISO fitting connections the shelter would most likely successfully pass the remaining end/side wall, railroad hump, and lashing tests. Results of the racking, dolly transport and drop tests, however, cannot be predicted.

DIRECTIONS FOR FUTURE STUDY

Based on the experience gained in this test program, additional research is warranted in the following areas:

(1) A second generation prototype ISO shelter has recently (December 1978) been fabricated. After completion of the normal series of acceptance tests and before any large scale production run, an instrumented transportation environment test study similar to this one should certainly be conducted with the second generation prototype.

(2) In addition to the previous study, an instrumented study of the new prototype, in the shelter configuration, to determine the response of the unit to climatic conditions such as wind, snow and solar loads should be conducted.

Table 9

Lower Transverse Lashing (Tension)
Microstrain Data[a]

Strain Gage	Load (Kilonewtons) 22	44.5	58.7[b]
1	−90	−230	−565
3	−20	−35	−20
5	+20	0	0
6	0	0	0
7	0	0	−20
8	0	0	0
9	0	−18	0
10	0	0	0
11	−35	−55	−70
16	0	0	0
17	+20	+20	+35
18	0	0	−35
22	0	0	0
23	0	0	0
24	0	0	0
31	+350	+650	+770
32	+350	+650	+755
33	+350	+650	+770
34	0	0	0
35[c]	–	–	–
36	0	0	0
37	0	0	0
38	0	0	0
39	0	0	0
43	0	0	0
44	0	0	0
45	+35	+35	+35
49	0	0	0

NOTES:

[a]Tensile values positive.

[b]End wall split at 58.7kN.

[c]Gage 35 not operating.

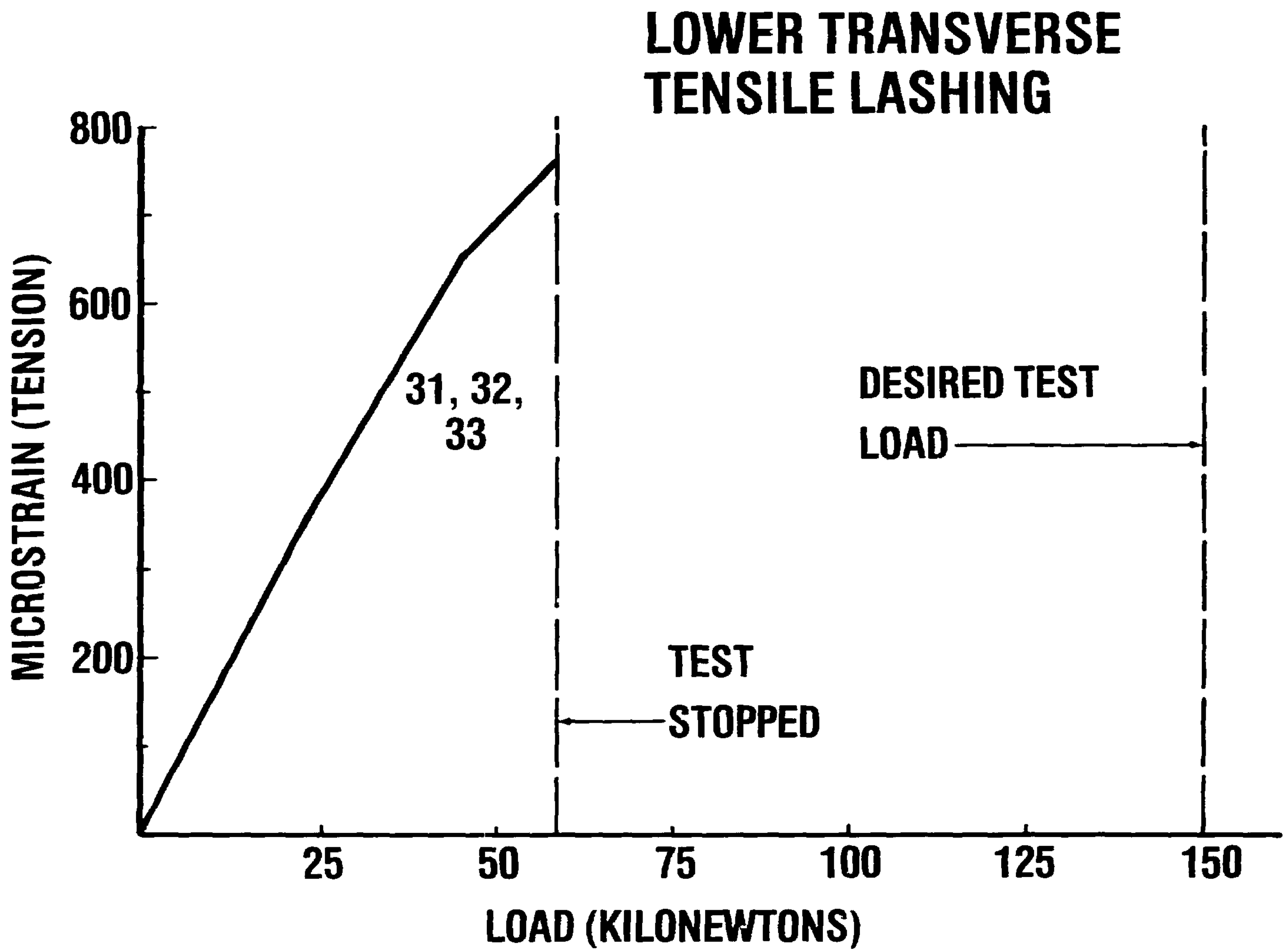


Figure 20. Lower Transverse Lashing (Tension) Strain Profile. Strain versus load for three most active gages (31, 32, 33).

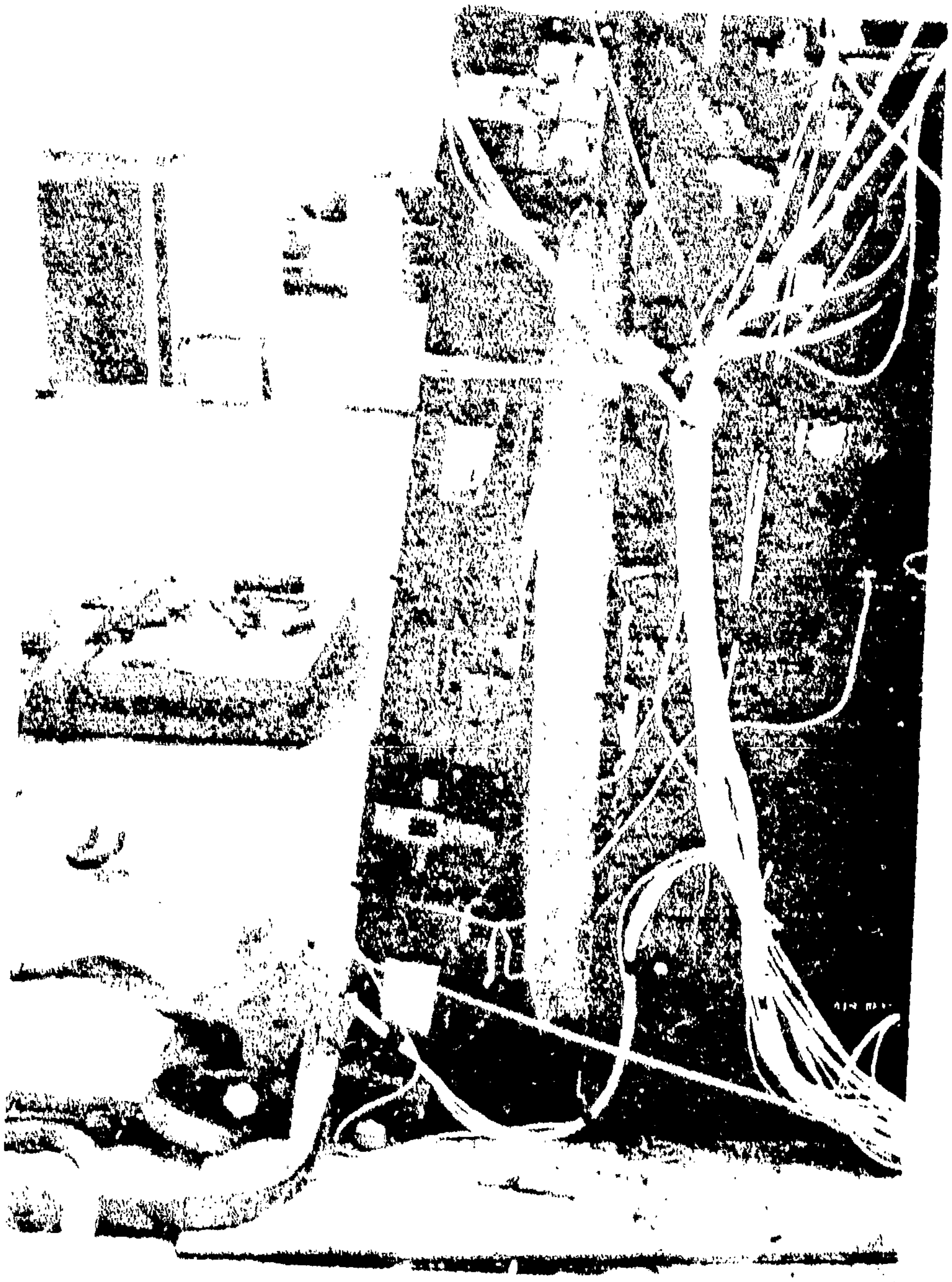


Figure 21. End Wall Failure. End wall split from base to roof as a result of tension load. Puddle visible near bottom left fitting formed by water which had been trapped in end wall.

Figure 22. Connecting Bracket Failure. Fractured connecting bracket which had secured the lower transverse channel to the ISO fitting.

(3) Historically, the free-fall drop test has been one of the most severe requirements imposed on a shelter/container combination. The absolute amplitude of the shock increases with the drop height and rigidity of the impact surface; but the relative difference, for example between a 30-cm and 45-cm drop on concrete or sand with a flat, edge or corner impact and the response of the container is not generally understood. Nor does a universally acceptable set of criteria exist upon which a drop test may be based. The possibility exists that shelters are overdesigned to meet an unrealistic drop requirement. A standard drop test is required for shelter/container combinations based on factual data relating the severity of different possible impacts and the probability of those impacts.

CONCLUDING REMARKS

The details of a study to experimentally measure the strains induced in a prototype rigid wall ISO shelter by loadings typical of the transportation environment have been documented. A series of tests which consider both ISO and military environments have been described. The strain and acceleration data generated during the tests are presented and are being used as an input to a complementary finite element analysis. Several design deficiencies in the area of joining of structural members were also revealed by structural failures under load. Three areas for a logical extension of future research are suggested.

This study comprises one part of a continuing research program being conducted by the US Army Natick Research and Development Command directed toward achieving the most efficient structural design for military tactical shelters.

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APPENDIX 3/1 SHELTER TRANSPORTATION ENVIRONMENT TEST PLAN

Load levels are based on a 2,722-kg (6,000-lb) shelter with a 4,082-kg (9,000-lb) payload capability and a 6,804-kg (15,000-lb) total gross mass.

TEST NO. I. STACKING.

Procedure. The shelter shall be placed on four level pads, one under each bottom corner fitting (see figure A-I.). The pads shall be centered under the fittings and be substantially of the same plan dimensions as the fittings. The container shall be loaded to a total gross mass of 12,247 kg (1.8 X 6804), (27,000 pounds).

A stacking load of 1,793 kN (20,321 X 5 X 1.8 X 9.8 X 10^{-3}) (403,200 pounds) shall be applied through four pads of the same plan area as the corner fittings, the load being equally divided among the four top corner fittings. Each pad shall be offset 3.8 cm (1.5 in) in the longitudinal direction and 2.5 cm (1.0 in) in the lateral direction.

Alternatively, corner structures may be individually tested to equivalent loads, 448 kN, or the corner structures on one end of the container may be tested simultaneously, and then the corner structures on the opposite end tested. If corner posts on one end frame are identical in design and section, except for being left and right hand, only one post per end frame needs to be stack tested. The offset of the corner fitting(s) shall be 3.8 cm (1.5 in) in the longitudinal direction and 2.5 cm (1.0 in) in the lateral direction.

In either case the load shall be applied for not less than 5 minutes.

TEST NO. 2. TOP LIFT.

Procedure. The shelter shall be loaded to a total gross mass of 18,167 kg (2.67 x 6,804), (40,050 pounds) and lifted from all four top corners, in such a way that no acceleration or deceleration forces are applied (see Figure A-2.). The lifting forces shall be applied at any angle between the vertical and 30° to the vertical.

The container shall be suspended for not less than 30 minutes and then lowered to the ground.

TEST NO. 3. BOTTOM LIFT.

Procedure. The shelter shall be loaded to a total gross mass of 18,167 kg (40,050 pounds) and lifted from all four bottom corners in such a way that no noticeable acceleration or deceleration forces are applied (see Figure A-3.). Lifting forces shall be applied using one spreader above the roof. Lifting slings shall be parallel to the sides and meet at the spreader approximately 61 cm (24 in) above the plane of the top corner fittings at midlength. No portion of the shelter shall touch the ground during this test, nor shall the lifting slings bear against the container walls, roof or similar superstructure.

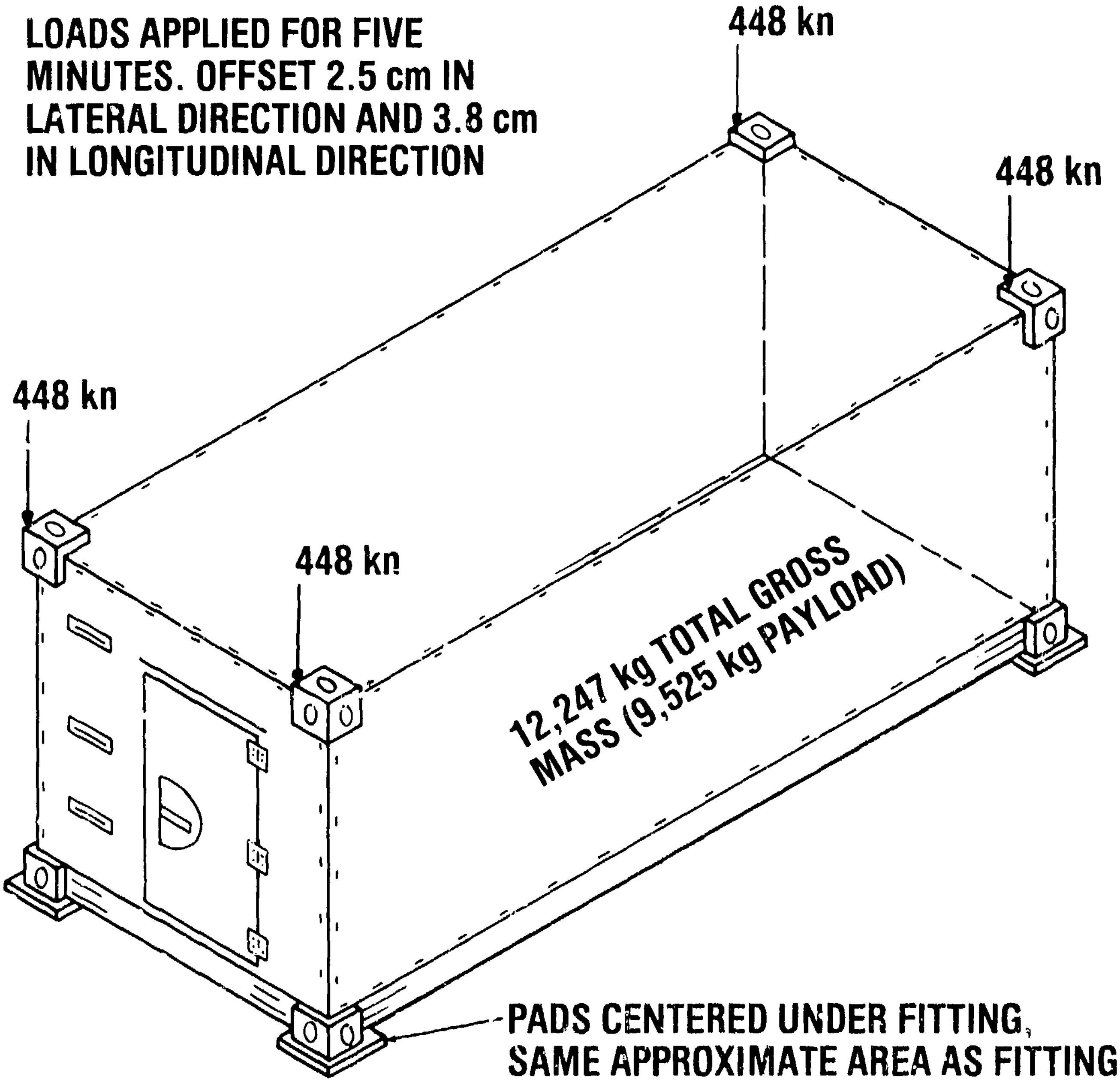

Figure A–1. Test No. 1. Stacking.

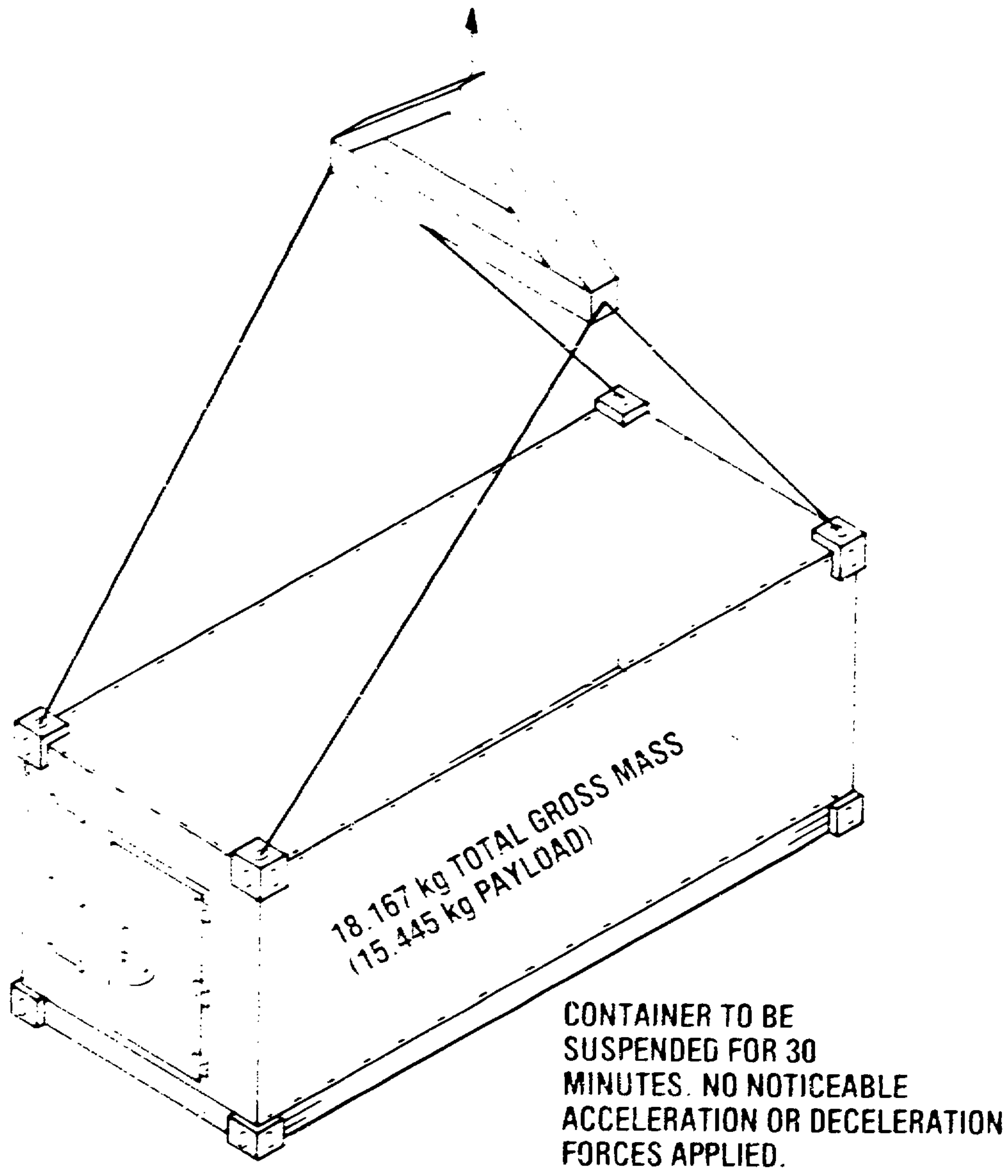

Figure A–2. Test No. 2. Top Lift.

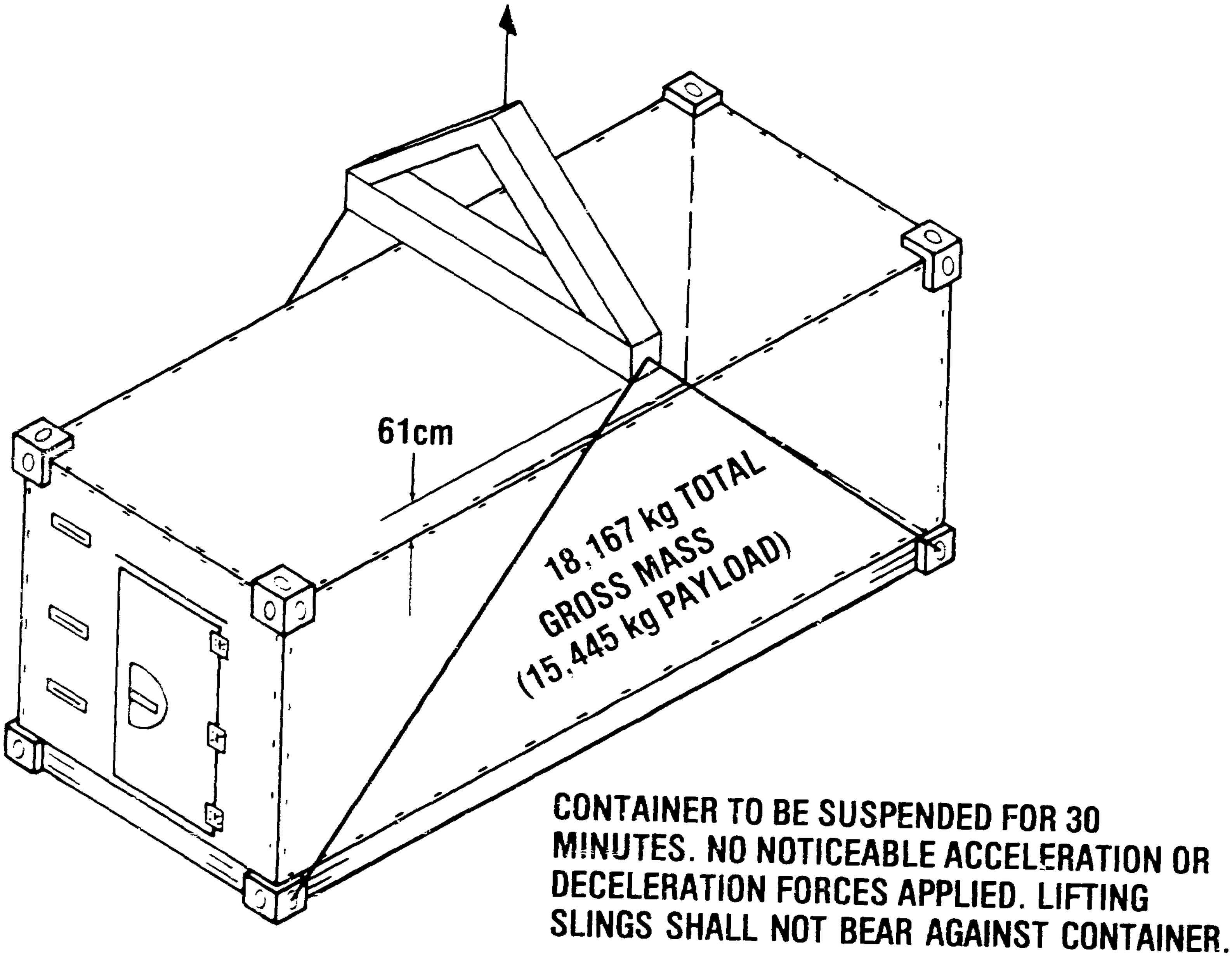

Figure A–3. Test No. 3. Bottom Lift.

The container shall be suspended for not less than 30 minutes and then lowered to the ground.

TEST NO. 4. RESTRAINT.

Procedure. The shelter shall be loaded to a gross mass of 6,804 kg (15,000 pounds) and shall be restrained longitudinally by securing the bottom corner fittings at one end to suitable anchor points through the bottom apertures (see Figure A-4.).

A force of 120 kN ($6804 \times 1.8 \times 9.8 \times 10^{-3}$), (27,000 pounds) shall be applied longitudinally to the container through the bottom apertures of the bottom corner fittings at the opposite end of the container, first in compression and then in tension.

Alternatively, a force of 60 kN (13,500 pounds) shall be applied to either side, first in tension and then in compression, or vice versa.

In either case, the force shall be applied and removed gradually and the load shall be applied for not less than one minute.

TEST NO. 5. RACKING

Procedure. The container under test shall be supported at all four bottom corner fittings on rigid pads lying in the same horizontal plane. (See Figures A–5a and A–5b.) The two bottom corner fittings diagonally opposite to the applied load which lie in the same side, perpendicular to the applied load, shall be totally restrained. The remainder of the bottom corner fittings shall be allowed to move only in a horizontal direction. There shall be no payload in the container. The forces shall be applied and removed gradually.

a. **Longitudinal Racking**

A compression or tension force of 150 kN (33,600 pounds) shall be applied to either of the two top corner fittings on one side of the container, the line of action of the force being horizontal and parallel to the sides of the container. Unless the sides are identical, both are to be tested consecutively.

b. **Transverse Racking**

A compression or tension force of 150 kN (33,600 pounds) shall be applied to either of the two top corner fittings on one end of the container, the line of action of the force being horizontal and parallel to the ends of the container. Unless the ends are identical, both are to be tested consecutively.

The container shall be subjected to first longitudinal and then transverse racking. The load shall be applied for not less than one minute.

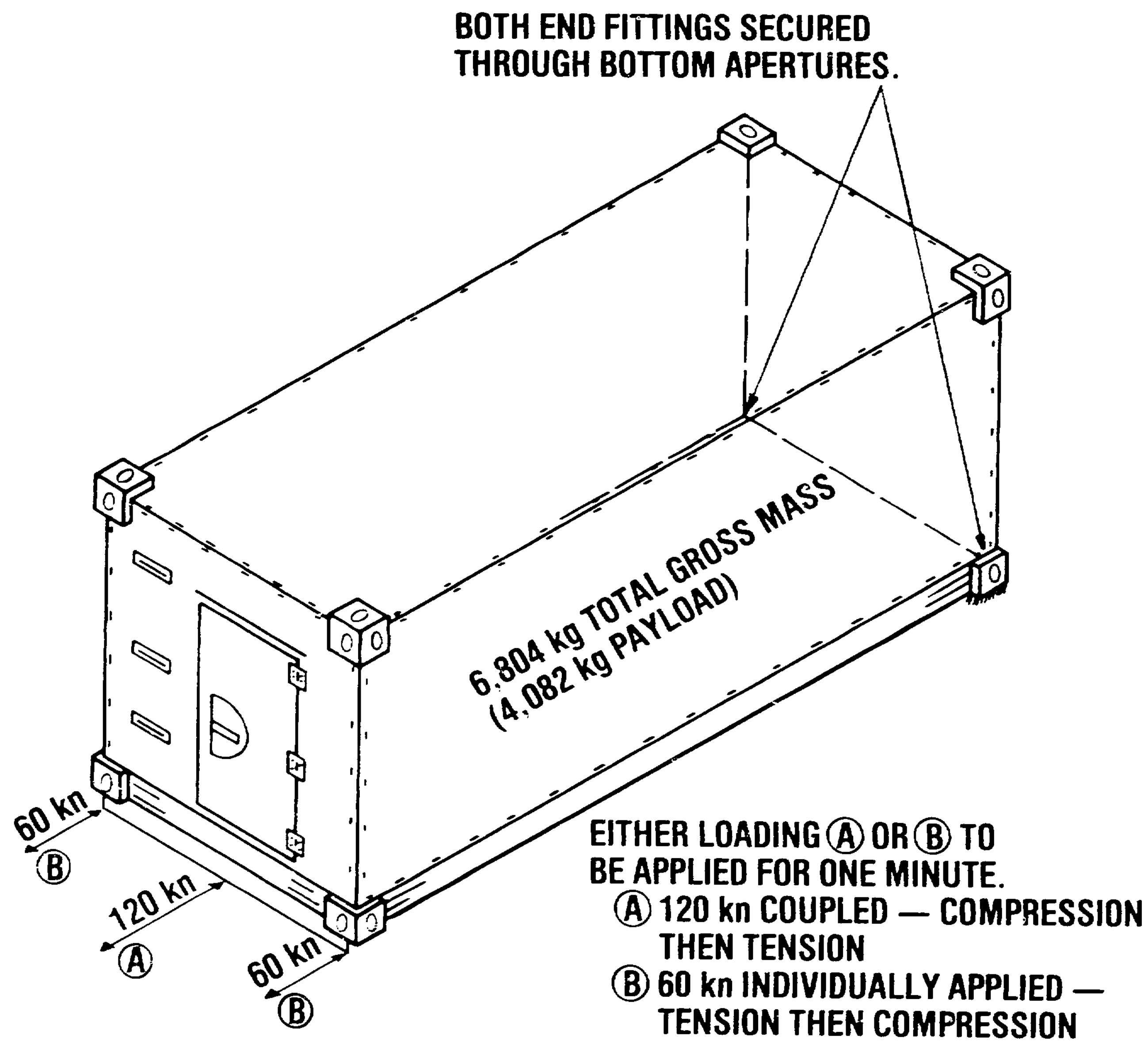

Figure A–4. Test No. 4. Restraint.

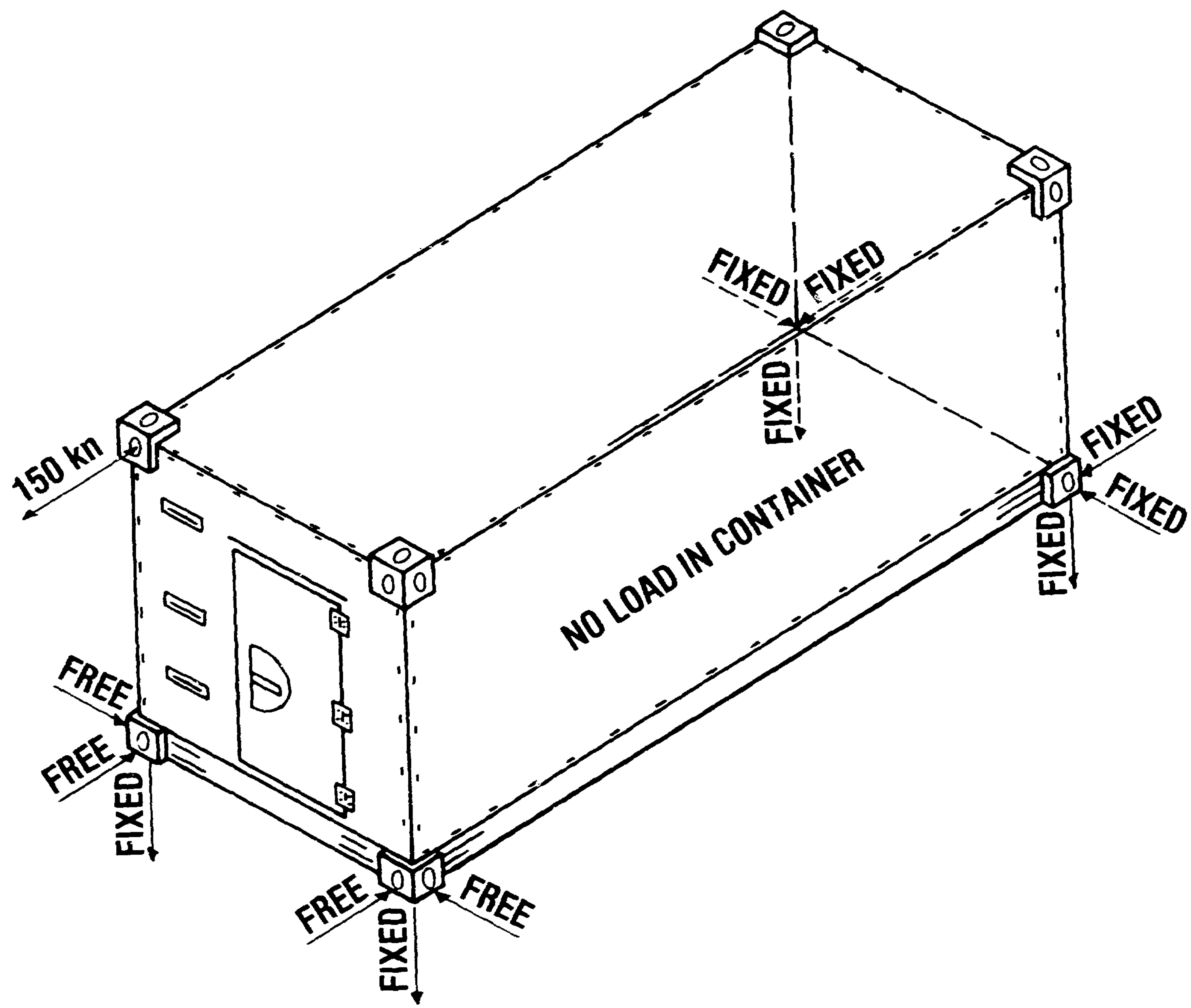

Figure A—5a. Test No. 5a. Longitudinal Racking.

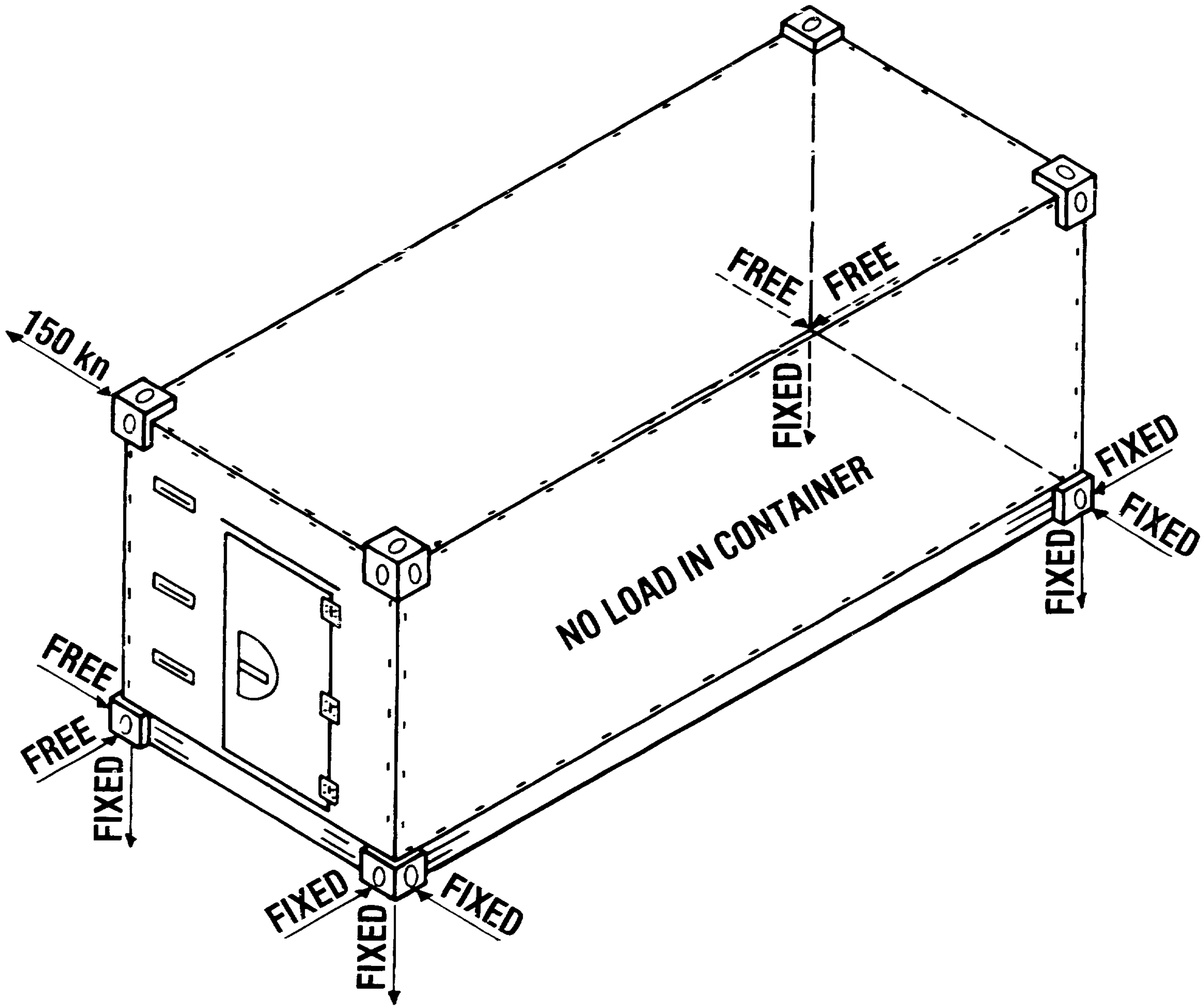

Figure A–5b. Test No. 5b. Transverse Racking.

TEST NO. 6. LASHING

Procedure. The container shall be resting on all four bottom corner fittings supported by rigid pads lying in the same horizontal plane. There shall be no payload in the container. (See Figure A–6.)

Compression or tension forces of the following magnitudes shall be successively applied to the appropriate corner fittings. The forces shall be applied to the two corner fittings that are in line with the structural member under test, and shall be induced through that face of the corner fitting perpendicular to the structural member. The forces shall be applied and removed gradually. The load shall be applied for not less than one minute.

Structural	Compression Load		Tension Load	
Member	kN	pounds	kN	pounds
Upper Transverse	100	22,400	150	33,600
Lower Transverse	150	33,600	150	33,600
Vertical Corner	300	67,200	100	22,400
Upper Longitudinal	0	0	100	22,400
Lower Longitudinal	150	33,600	150	33,600

TEST NO. 7 END WALL

Procedure. The container shall have each end tested when one end is blind and the other is equipped with doors. (See Figure A–7.) When both ends are identical only one end need be tested.

A force of 27 kN ($0.67 \times 4082 \times 9.8 \times 10^{-3}$), (6,030 pounds) shall be uniformly distributed over the end wall.

The load shall be applied for not less than 5 minutes.

TEST NO. 8. SIDE WALL

Procedure. The container shall have one side wall tested when both sides are identical. (See Figure A–8.) If the two side walls are not the same, both must be tested.

A force of 27 kN ($0.67 \times 4082 \times 9.8 \times 10^{-3}$), (6,030 pounds) shall be uniformly distributed over the side wall.

The load shall be applied for not less than 5 minutes.

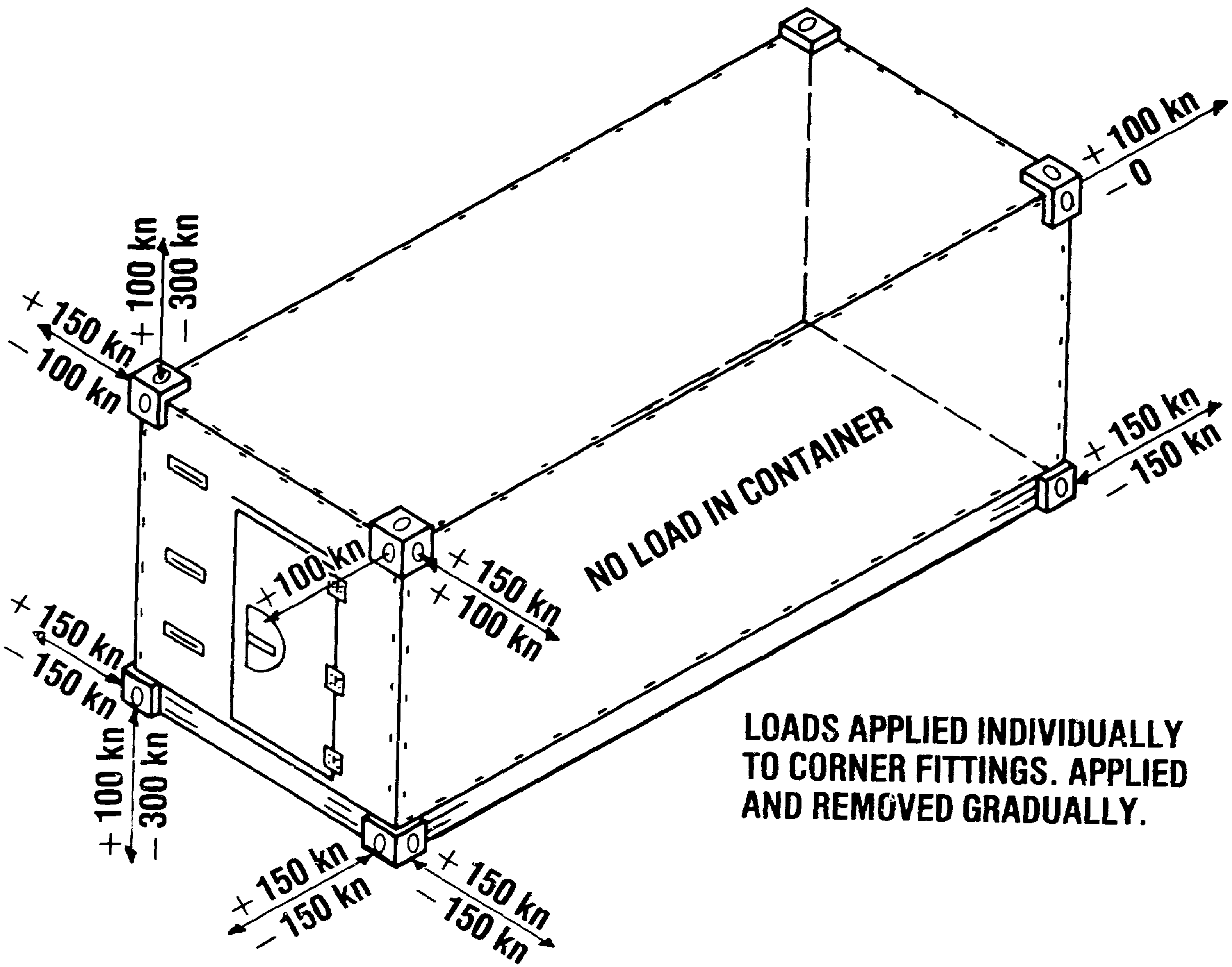

Figure A–6. Test No. 6. Lashing.

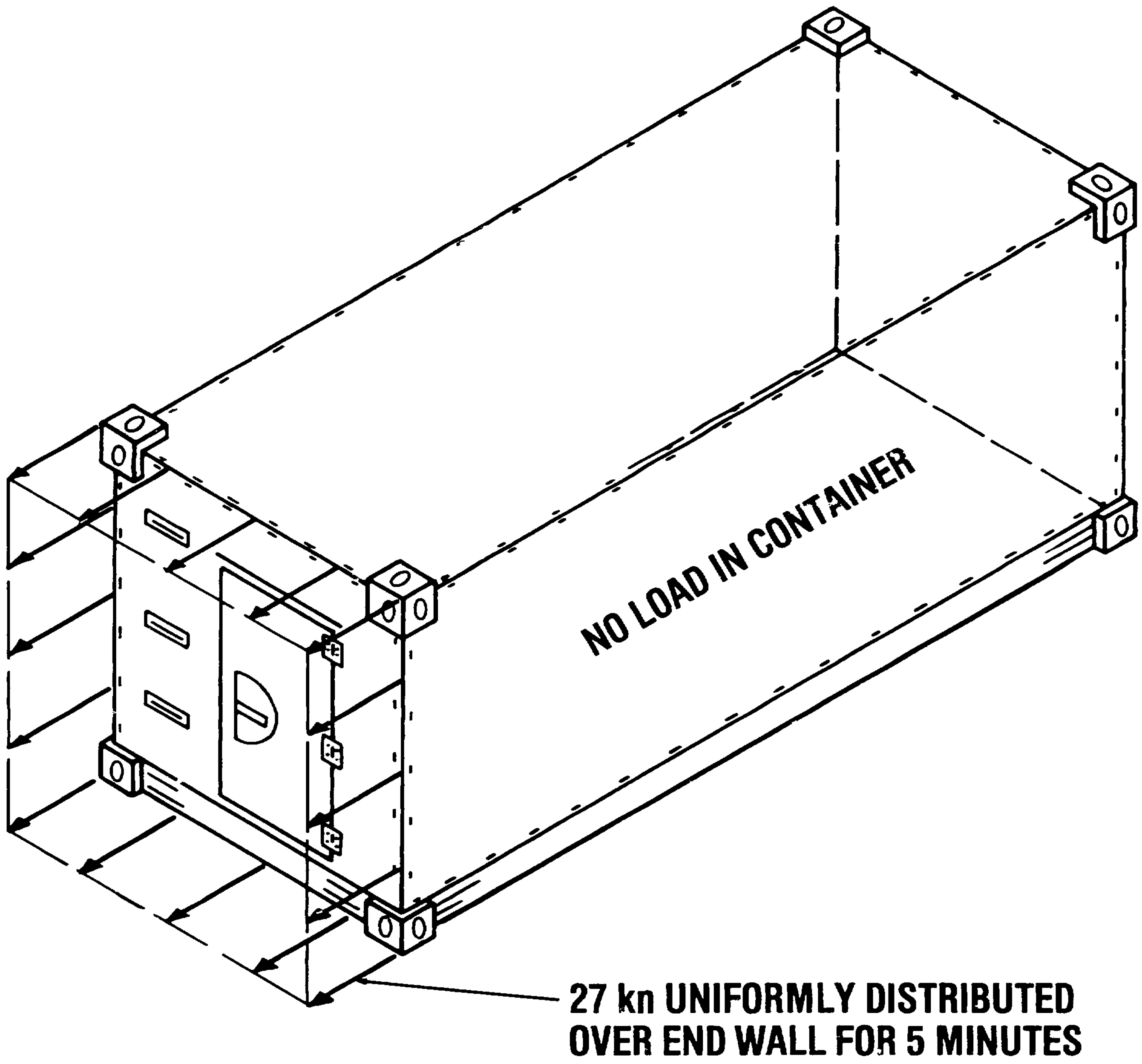

Figure A–7. Test No. 7. End Wall.

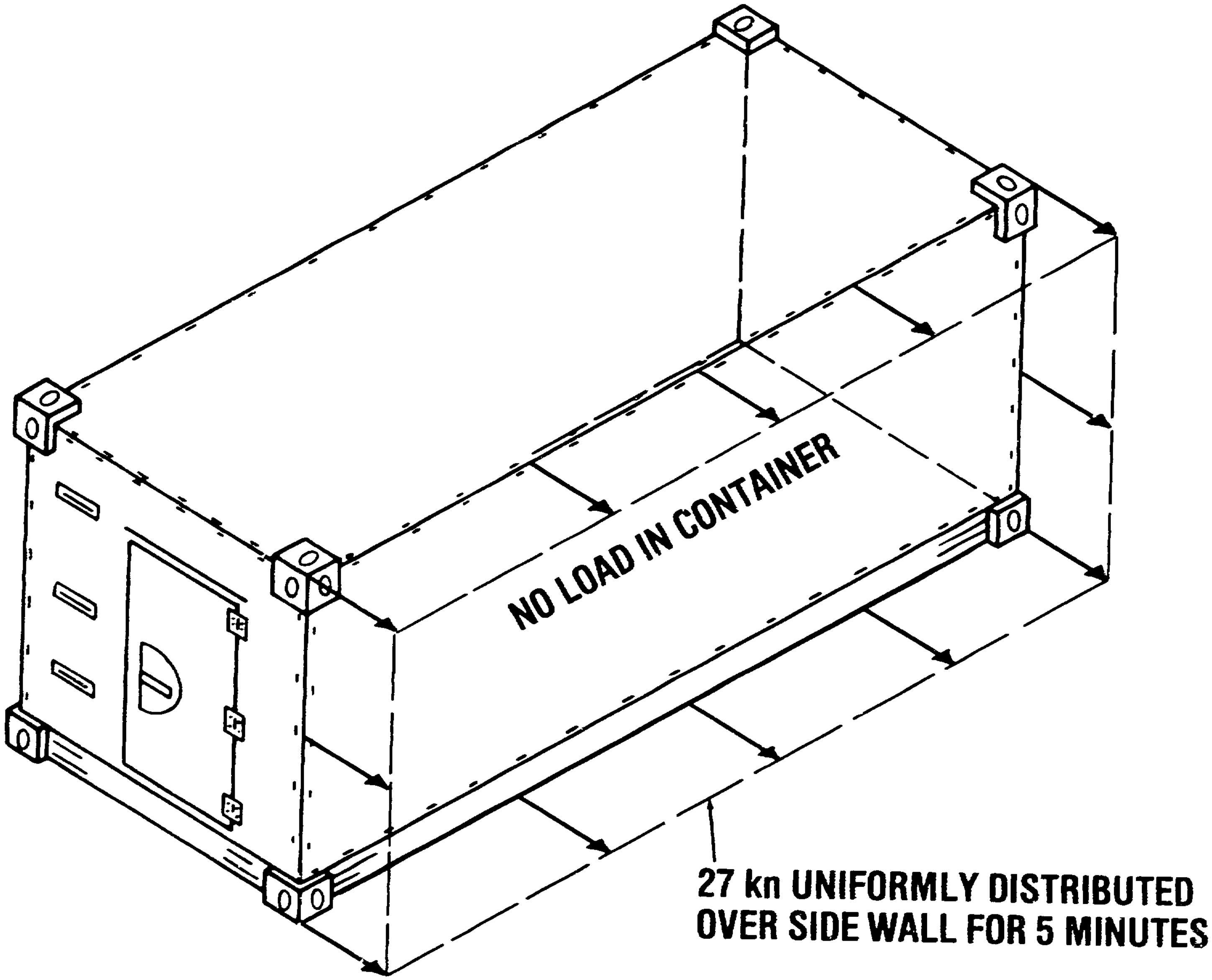

Figure A–8. Test No. 8. Side Wall.

TEST NO. 9. ROOF

Procedure. A concentrated load of 300 kg (660 pounds) shall be uniformly distributed vertically down over an area of 61 cm (24 in.) by 30 cm (12 in.) located so as to have the most adverse orientation with respect to the unsupported area of the roof sheet. (See Figure A–9.)

The load shall be applied for 5 minutes minimum.

TEST NO. 10. RAILROAD HUMPING

Procedure. The shelter loaded to a gross mass of 6,804 kg (15,000 pounds) shall be secured to a railroad flat car in a normal manner. (See Figure A–10.) In addition, there shall also be required one standard railroad box car coupled to one standard railroad gondola car loaded to 18,144 kg (20 tons). These cars shall be equipped with standard gear coupling and the air brakes shall be set in emergency application position on both cars. The test car, traveling at 14.5 km/hr (9 mph) plus or minus 0.8 km/hr (0.5 mph) on a flat stretch of track, shall be impacted against the two stationary cars. The test shall be repeated with the impact being made in the opposite direction.

TEST NO. 11. DROP

Procedure. The shelter shall be loaded to a gross mass of 6,804 kg (15,000 pounds).

a. **Cornerwise Drop** (See Figure A–11a)

One corner of the base of the shelter shall be supported on a block nominally 15 cm (6 in.) in height and a block nominally 30 cm (12 in.) in height shall be placed under the other corner of the same end. The unsupported end of the shelter shall be raised so that the lower corner reaches a height of 30 cm (12 in.) and is then allowed to fall freely onto a concrete surface. This test shall be repeated for the diagonally opposite corner of the base.

b. **Edgewise Drop** (See Figure A–11b)

The container shall be placed on its bottom with one end of the base of the container supported on a sill nominally 15 cm (6 in.) high. The unsupported end of the container shall then be raised 30 cm (12 in.) and allowed to fall freely on a concrete surface. This test shall be repeated for the opposite end of the container base.

TEST NO. 12. TRUCK TRANSPORT

Procedure. The shelter shall be loaded to a gross mass of 6,804 kg (15,000 pounds) and secured on a standard semi-truck trailer. The following surfaces will then be traversed at the speeds indicated:

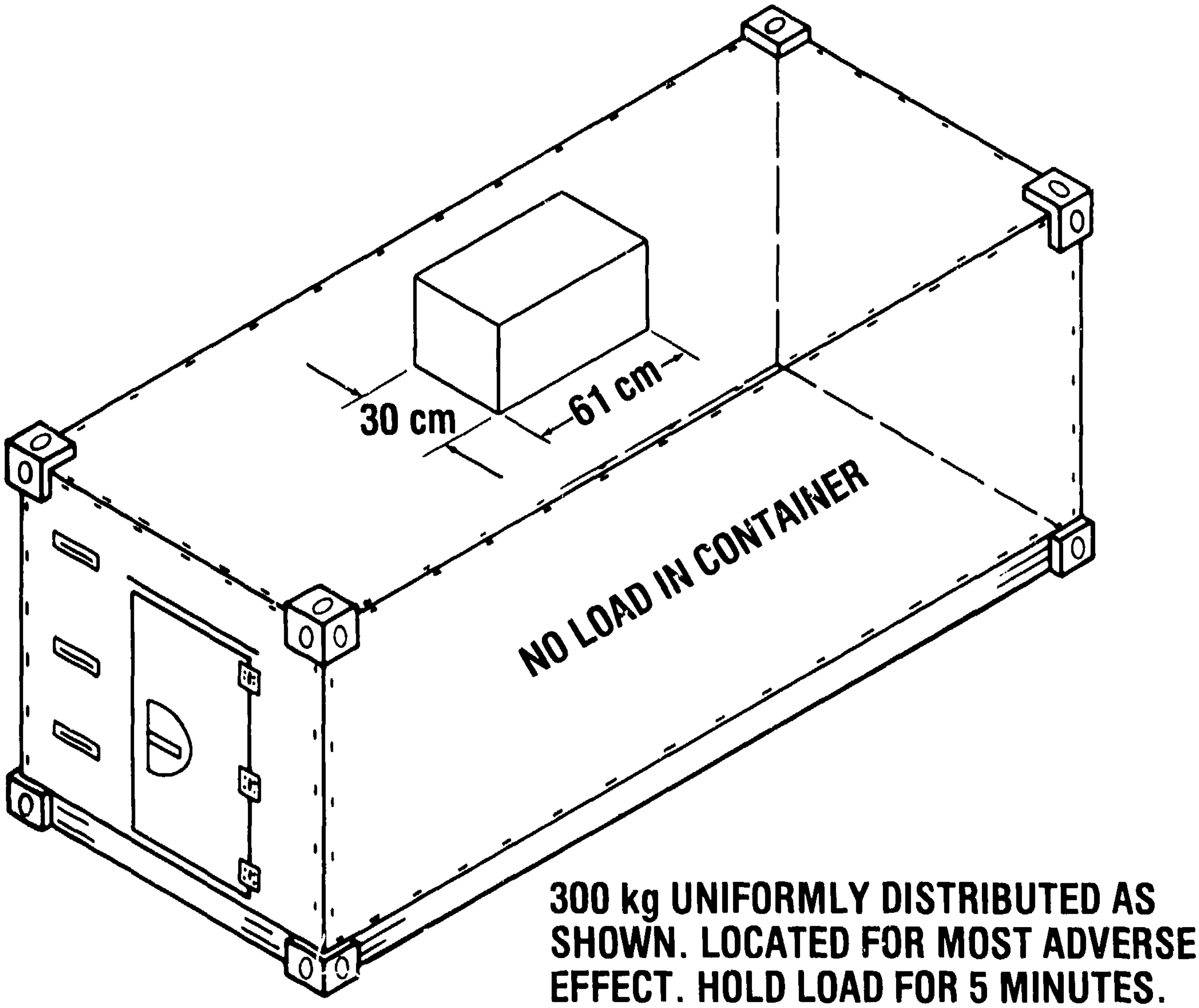

Figure A–9. Test No. 9. Roof.

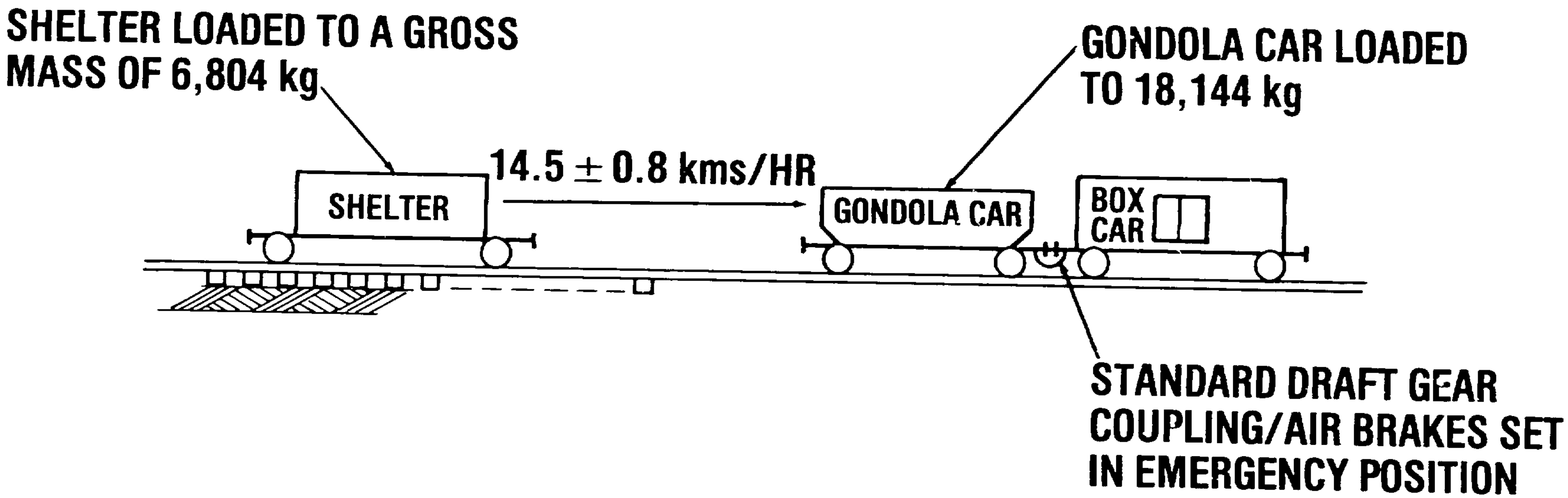

Figure A–10. Test No. 10. Railroad Humping.

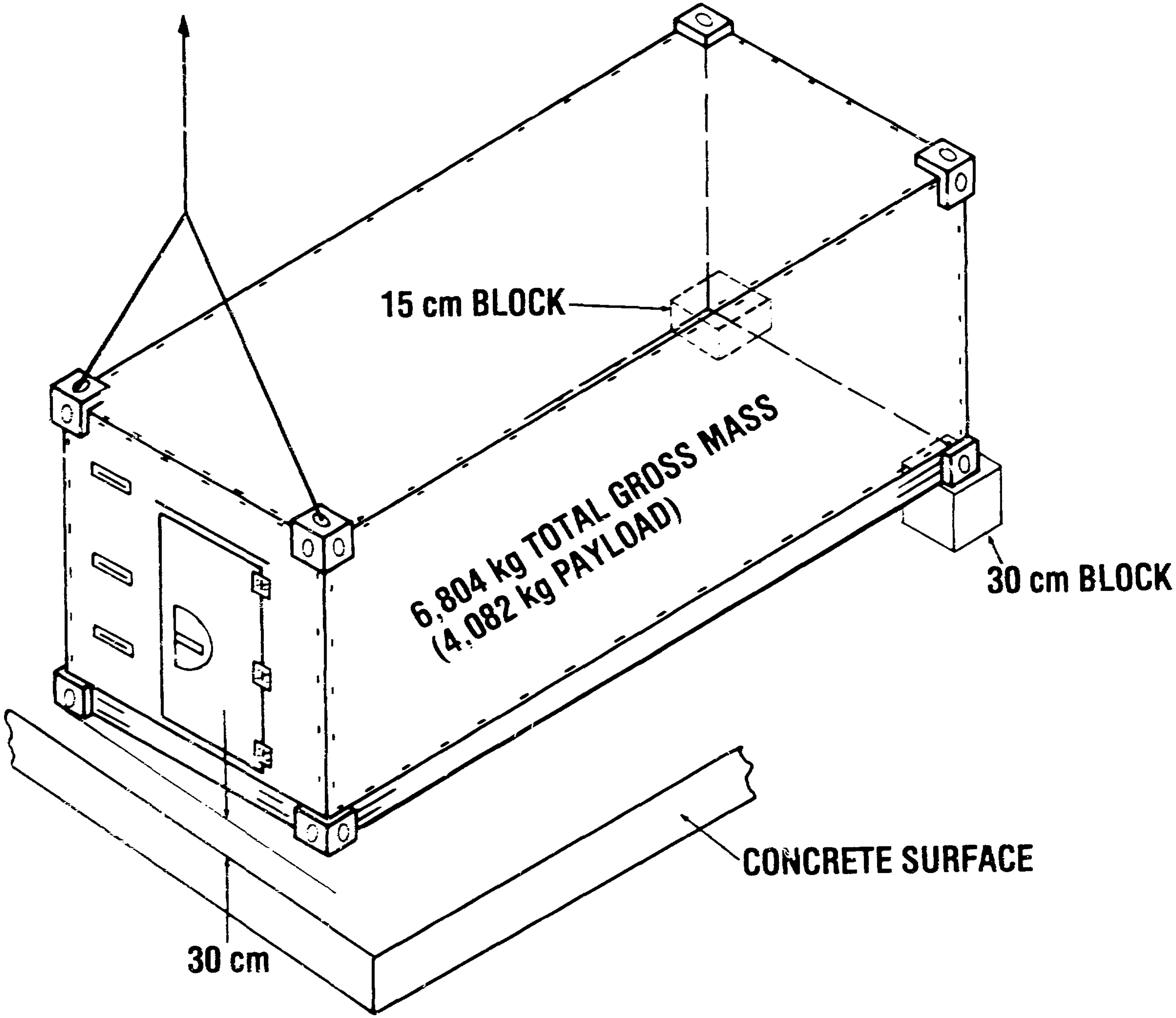

Figure A–11a. Test No. 11a. Cornerwise Drop.

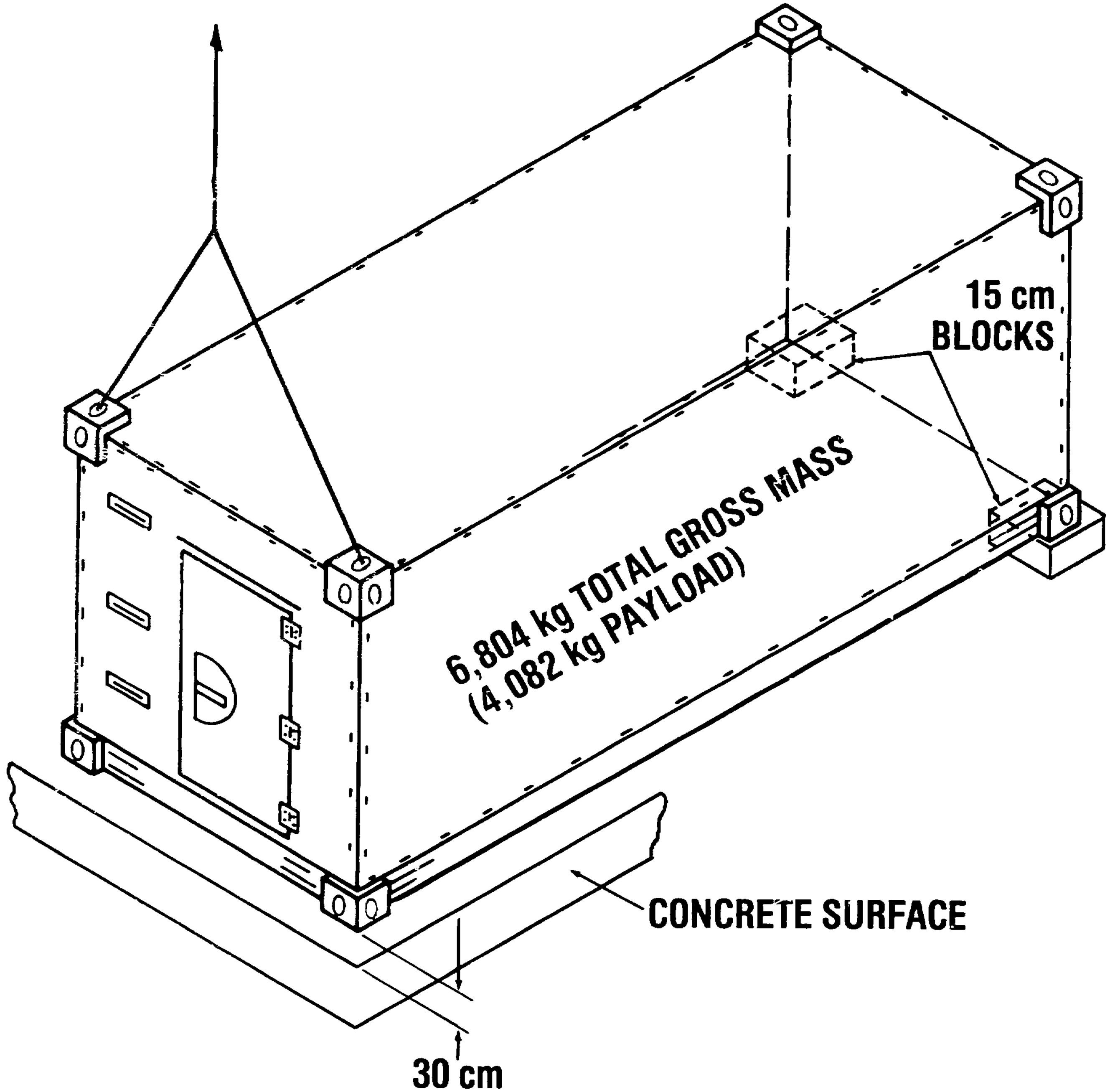

Figure A-11b. Test No. 11b. Edgewise Drop.

Surface	Average Speed km/hr	mph	Maximum Speed km/hr	mph	Distance km	miles
Paved Highway	80	50	97	60	32	20
Gravel Road	32	20	40	25	16	10
Cross Country	25	15	32	20	8	5

TEST NO. 13. DOLLY TRANSPORT

Procedure. Identical to previous test except unit is secured to transporter dolly.

TEST NO. 14. TOWING

Procedure. The shelter loaded to a gross mass of 6,804 kg (15,000 pounds) shall be towed for a minimum of 91 metres (30 ft) forward and 91 metres (300 ft) backward over rough plowed ground at a speed of 8 km/hr (5 mph). Four right-angle turns shall be performed on soft dirt while the shelter is being towed.